REPORT

2

FINAL REPORT

U.S. ARMY CHEMICAL, RESEARCH,

DEVELOPMENT AND ENGINEERING CENTER

INDIVIDUAL PROTECTION EQUIPMENT

DESIGN WORKSHOP

To

U.S. ARMY CHEMICAL, RESEARCH,

DEVELOPMENT AND ENGINEERING CENTER

JANUARY, 1990

Battelle
. . . Putting Technology To Work

Chemical-Biological
Information Analysis
Center

BATTELLE EDGEWOOD OPERATIONS/CBIAC

2113 EMMORTON PARK ROAD, SUITE 200

EDGEWOOD, MARYLAND 21040

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Task 151	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Battelle - CBIAC 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 2113 Emmorton Park Road Suite 200 Edgewood, MD 21040	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army CRDEC 8b. OFFICE SYMBOL (If applicable) SMCCR-PPI	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DLA900-86C-2045
8c. ADDRESS (City, State, and ZIP Code) Edgewood Area, APG MD 21010-5423	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
US Army Chemical, Research, Development and Engineering Center Individual Protection Equipment Design Workshop.

12. PERSONAL AUTHOR(S)
Brletich, Nancy R.

13a. TYPE OF REPORT	13b. TIME COVERED FROM ______ TO ______	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
		January 1, 1990	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Individual protection equipment, conference proceedings, masks, RESPO 21, design concepts, design workshop.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Chemical Research, Development, and Engineering Center (CRDEC), Physical Protection Directorate hosted the Individual Protective Equipment Design Workshop. 17-19 October 1989. The purpose of the workshop was to establish design criteria for Respiratory Protective System 21 (RESPO 21). A panel of experts from both industry and government were invited to participate in the workshop. Additionally, members of the user community were also invited to provide their input into the design requirements for RESPO 21. CRDEC personnel presented, for comment, three initial design concepts which may eventually be incorporated wholly, or in part, into RESPO 21. The three design concepts include a softshell designation, a semi-rigid designation and a hardshell (modular) designation.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

FINAL REPORT

Contract No. DLA900-86-C-2045

on

U.S. ARMY CHEMICAL, RESEARCH, DEVELOPMENT
AND ENGINEERING CENTER
INDIVIDUAL PROTECTION EQUIPMENT DESIGN WORKSHOP

to

U.S. ARMY CHEMICAL, RESEARCH, DEVELOPMENT
AND ENGINEERING CENTER

January 1, 1990

by

Nancy R. Brletich

Battelle Edgewood Operations - CBIAC
2113 Emmorton Park Road
Edgewood, MD 21040

Table of Contents

FIGURES

TABLES

EXECUTIVE SUMMARY

The Chemical Research, Development, and Engineering Center (CRDEC), Physical Protection Directorate hosted the Individual Protective Equipment Design Workshop, 17-19 October 1989. The purpose of the workshop was to establish design criteria for Respiratory Protective System 21 (RESPO 21). A panel of experts from both industry and government were invited to participate in the workshop. Additionally, members of the user community were also invited to provide their input into the design requirements for RESPO 21. CRDEC personnel presented, for comment, three initial design concepts which may eventually be incorporated wholly, or in part, into RESPO 21. The three design concepts include a softshell designation, a semi-rigid designation and a hardshell (modular) designation.

The primary recommendation provided was that each of the three respirator concepts introduced do indeed hold merit, therefore, each concept should be pursued to the next stage of development, system prototype production. In addition, further evaluation of each of the concepts should be pursued. However, prior to evaluation each of the concepts must be further defined. In addition, it was recommended that a comprehensive, multi-threat analysis be performed as performance and protection capability become more critical issues. Finally, a preliminary trade-off analysis is required particularly because a 100 percent solution to the performance decrements imposed by IPE is impossible to obtain utilizing current technologies. A more feasible approach appears to be to incorporate an 80 percent solution. The aforementioned recommendations should be completed prior to holding Design Workshop Two.

The conclusions reached at the 1989 Design Workshop are outlined below:

- Continued CRDEC/NRDEC development coordination is essential.
- Evolutionary designs with new requirements are expected.
  - Potential future requirements include:
    - Increased Chemical/Biological protection
    - Increased physiological requirements
    - Multiple threat protection
  - Early trade-off determinations must be supplied for user evaluation.
- Old ideas should be revisited with new design technologies. Highly desirable designs can be derived from incremental improvements to components and through the use of increased modularity.
- Full face ballistics protection is a design driver.

- Designs must interface with the SIPE headgear.
- Lenses must be close to the eye to assure compatibility.
- Reduced threat filters are not desirable.
- Improved communication is essential.

1.0 INTRODUCTION

The Chemical Research, Development, and Engineering Center's Physical Protection Directorate hosted the Individual Protective Equipment Design Workshop, 17-19 October 1989. The purpose of the workshop was to establish design criteria for Respiratory Protective System 21 (RESPO21). The RESPO 21 program was initiated to develop a mask to replace the M40/M42 protective series. Front End Analysis has indicated that improvements in the following areas are desirable in the RESPO 21 concept:

- o Minimization of Mission Degradation
  - Thermal Burden
  - Respiratory Burden
  - Metabolic Burden
  - Human Factors Burden
    - -- Biomechanical
    - -- Sensory
  - Psychological
- o Improved System Integration
- o Improved Compatibility

While demonstrating product improvements in the aforementioned areas, the RESPO 21 respirator should maintain current required levels of protection.

1.1 Summary of IPE Workshop, 12-14 October, 1988

The design workshop was a follow-up of the Individual Protective Equipment Technology Workshop held during 12-14 October, 1988, whose objective was to assess the current and future technologies which may be applicable to Individual Protection Equipment, IPE. The conclusions and recommendations drawn from the 1988 workshop as reported in the conference proceedings were:

Conclusions:

- o IPE is a very complex area of chemical defense. Research and development in this area requires a large number of activities and disciplines (Polymers and Textiles, Filtration, Chemistry of Agents, Power Supplies, Human Engineering, etc.). Important complexities are the sometimes divergent perceptions of the problems and solutions on the part of the developer and the user.

- o The present IPE, including the protective ensemble and the mask, provides excellent protection against known chemical agent threats, with carbon being the likely filtration media for the foreseeable future. The defects with the present equipment are the additional physiological and psychological

burdens placed on the individual and his inability to carry out the mission efficiently and effectively while wearing the equipment.

- IPE gear will always impose some hardship to the wearer, but many diverse improvements can be made to lower the present distress level. This will require some trade-off decisions by the user and the doctrine. The present doctrine does not always reflect what may be the actual environment on the chemical battlefield. Much can be accomplished by more wisdom in the doctrine and better training.

- In the past, items of IPE gear appear to have been designed separately without much regard to the other items. This has often resulted in individual items of IPE which perform their designed role very well but may not interface or synergize well with other items of IPE.

- A major principle for reducing the burden of IPE is to make adaptable equipment so that items might be adjusted to the severity of the threat and not provide excessive protection if it is not necessary.

- There is a misconception on the part of some that head cooling alone will significantly ameliorate or even solve the thermal burden predicament. Thermal burden is a total body issue, and microclimate cooling appears to be the only solution to relieving the heat stress of IPE.

- Some past decisions in the choice of IPE seem to have been driven by the need to reduce the logistics at the expense of having effective equipment. The choice of the universal fitting bootie which has just been replaced is a perfect case in point. Logistics cannot be the main driver in such choices though the panel realizes the importance in this facet.

- Providing appropriate power sources to handle the multitude of functions which future IPE will be asked to perform, especially microclimate cooling, is a difficult task. There are virtually no single technology options that will provide sufficient power over required periods of time while falling into acceptable weight parameters. However, the combination of a hybrid power source, a hybrid approach to microclimate cooling, and an adaptable IPE system may permit sufficient power to be provided even using present technology.

<u>Recommendations</u>:

- The program goals should be to achieve and maintain total system protection, apply micro-climate control to reduce whole body physiological burden, improve training and individual recognition, and take advantage of operational and threat flexibilities.

- The next generation of IPE should invoke a systems approach to develop an integrated set of equipment. Such an approach may require changes in the organization of the laboratories involved in IPE R&D.

- The program should use a coordinated systems approach with emphasis on technology identification, development of systems parameters (including operational threat parameters), model integration and validation, and parallel test development. This systematic program approach should be used to define future system parameters before attempting to finalize concept options, while attempting to achieve acceptable performance levels with a significant reduction in the current burden to the soldier.

- With the further development of polymers and the improvements in design and manufacturing, a specific reassessment of a full vision respiratory system, incorporating corrective lenses, low interior volume (to facilitate recognition) and anti-fogging design, should be made, leading to the development of a system which provides improved facial recognition with lower burden.

- Threat and operational conditions should be reviewed with the user community and the schools to identify revolutionary designs not readily apparent through technology.

- Hybrid approaches to microclimate cooling, as well as power sources for all IPE power needs, should be investigated as a priority since no single technology in either discipline is mature enough to provide individual solutions.

- Producibility should always be included as a criterion in evaluating options throughout the lifecycle of IPE development. "Design to manufacture" should be a primary consideration in each stage of development.

1.2 Intervening Progress - October 1988 through Present

Since the 1988 workshop, CRDEC has been conducting research incorporating the conclusions and recommendations described above. The work has led to the establishment of three preliminary respirator design concepts. These three design concepts were essentially "straw dogs" whose purpose was to promote discussion and establish a frame of reference. Experts from both the government and industrial arena were invited to critique these three initial respirator designs which may eventually be incorporated into RESPO 21.

An additional feature of the conference was the inclusion of the user community to obtain their input into the requirements for RESPO 21. Invitations were sent to all the major schools and centers. Representatives from the Chemical School, Infantry School, Armor Board, Ordinance Center and School, and U.S. Navy

were among the attendees.

This workshop proceeding contains a summary of the concept evaluations, new concepts introduced during the workshop, and major recommendations and conclusions presented by both the user community and the panel of experts.

2.0 WORKSHOP BRIEFINGS

The workshop was initiated with a series of technical briefings which served to provide background regarding the prior 1988 RESPO 21 Technology Workshop, present the design criteria for RESPO 21, and stimulate discussion regarding the three initial RESPO 21 concepts introduced by the technical staff of the Physical Protection Directorate, CRDEC.

The detailed briefings are appended. The topic, presenter, and his/her organization follow:

- Appendix C - IPE Technology Workshop Review
  Mr. Corey M. Grove, US Army CRDEC
- Appendix D - Chemical/Biological Threat Overview
  Mr. Charles R. Crawford. US Army CRDEC
- Appendix E - Future Compatibility Requirements
  Mr. David M. Harrah, US Army HEL
- Appendix F - Operational Priorities
  Ms. Stephanie Clewer, US Army CRDEC
- Appendix G - Physiological Requirements
  Dr. Ronald A. Weiss, US Army CRDEC
- Appendix H - Soldier Integrated Protective Ensemble, SIPE Overview
  Ms. Carol J. Fitzgerald, US Army NRDEC

3.0 USER PERSPECTIVES

One of the key goals of the workshop was to establish the user perspectives regarding the development of RESPO 21. The following is a summary of the comments and recommendations expressed by representatives from the user community:

United States Army Infantry School

- Integrate sighting/vision systems in RESPO 21 rather than being only compatible with these systems.
- To maximize the effectiveness of future weapon systems soldiers will be more dispersed across the battlefield requiring greater communication capabilities and increased mobility.
- Need integrated balanced multi-threat protection.
- Recommend review of Army Science Board Report dated 23 July 1984.
- Exploit improved range of weapon sighting in RESPO 21.
- Use the Small Arms Master Plan to determine future integration needs.
- Look to integrate RESPO 21 with the man-portable weapon systems soon to be fielded.
- Develop a modular system to allow user to tailor the system to address individual and multi-mission requirements.

United States Army Armor School

- Continue the systems approach.
- Threat will continue to increase, consequently may need to encapsulate to address additional threats beyond Nuclear, Biological, and Chemical.
- Need to incorporate blast/overpressure protection.
- RESPO 21 should be modular in order to allow new technologies to be incorporated.
- Need improvements in helmet/mask interface.
- Positive pressure within the mask may be needed to achieve desired levels of protection.
- Cost of RESPO 21 is important.

Unites States Army Ordnance School

- o Need RESPO 21 to be more compatible with combat systems.
- o Future air/land battlefield will move away from fixed sites requiring greater mobility.
- o More mobile maintenance will be done in the future.

United States Army Chemical School

- o Continue with gains from M40 including improved protection and comfort.
- o Incorporate food ingestion capability.
- o Need enhanced communication and visibility particularly in peripheral field.
- o Would like to be able to change the filters in a contaminated environment.
- o Need to incorporate modular concept, as well as component commonality, in order to improve logistics.
- o Need increased level of protection in order to meet the challenge of new threats.

In summary, among the key issues discussed were the need to keep abreast of the changing threat; incorporation of a modular design to meet differing needs of the various users and the desire for an integrated system.

4.0 EXPERT COMMENTARY

Several of the experts attending the conference were asked to elaborate on critical issues pertaining to the development of the RESPO 21 concept. This section is devoted to allowing these experts to present their commentary.

The following viewpoints reflect the opinions of each respective author and are not necessarily shared by the Chemical Research, Development and Engineering Center's Physical Protection Directorate or the RESPO 21 project manager. Furthermore, the ideas presented are strictly suggestions, serving to stimulate discussion or dialogue. These ideas will not necessarily be adopted in the RESPO 21 concept.

4.1 Building on Past Military Successes
By Dr. Frank Shanty

The M40 series of protective masks represents the culmination of many years and many millions of dollars of R&D investment. Applicable state of the art technologies were incorporated into these designs.

The M40 designs were largely the result of evolutionary advances over the predecessor designs (i.e. M17, M24, M25, and M8 series masks). Continuation of this incremental advancement of design is an important approach in the development of a successor series of respiratory protective equipment.

The next respiratory protective system must offer significant gains over the M40 series. One economical way to apply evolutionary design is to seek new designs which retain the best features of the M40, and apply R&D resources to address those areas wherein the M40 needs improvement. While acceptance by the user of the M40 series appears to be good, the user has identified specific areas of needed improvement.

On the basis of these user reactions and the developers understanding of the threat, the following points are suggested as guidance for creating candidate new evolutionary designs:

1. Retain or improve M40 protection factor performance.

2. Retain M40 filter life for physically adsorbed agents.

3. Retain or improve M40 comfort.

4. Improve M40 vision features (i.e. Field, Binocular, Sighting).

5. Enhance communications capability compared to the M40 for both speech transmission and hearing through the hood.

6. Reduce inhalation/exhalation resistances.

7. Improve wearer recognition.

8. Provide operational versatility through modular features adaptable to specific operational needs particularly for communication and vision.

Even in an effort to create a revolutionary new design, the above criteria can be used as a minimum basis for preliminary evaluation of the design.

4.2 Filter Concepts
Written By Mr. John Boardway

The Army can no longer afford the luxury of designing filtration systems which can be expected to provide NBC protection under all conditions. Requirements must realistically reflect an expectation of casualties under extreme conditions. Filter design concepts must be tailored to the following:

1. Threat and threat probability.

2. Breathing and/or ventilation flowrates required.

3. Reasonable capacities and replacement criteria.

4. Mounting location (on and off the face) and attachment mechanism.

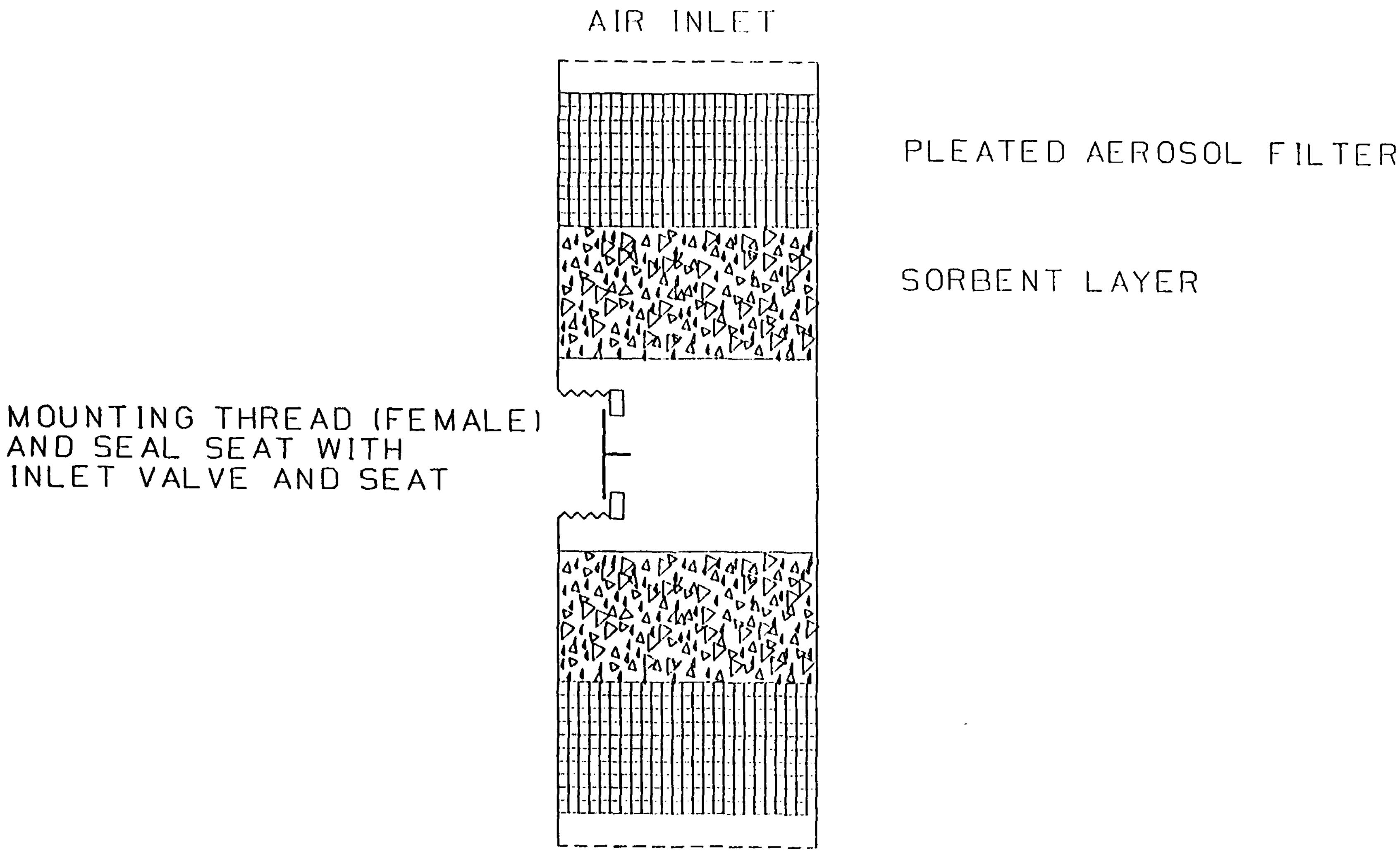
5. RAM-D (Reliability, Availability, Maintainability, and Durability)

Unknowns in the threat equation make it highly desirable that some provision be made for rapid filter change and/or protection enhancement (i.e. increased capacity or different sorbents) without major system modifications. Discussions indicate that current levels of agent protection (vapor and particulate) are adequate but that increased physical activity (i.e. breathing rates) result in breathing resistance problems and may, for some agents, compromise vapor protection. This requires filter designs which will increase the filtration area for both the aerosol filter and the sorbent bed. In addition, multi-protection requirements and other improvements sought, dictate that the filter system will likely have to be mounted off the facepiece and may require blower assistance for movement of air through the filter(s) and hose(s) to the facepiece. In view of the above, the radial flow canister bed design should be considered and thoroughly evaluated. Without material changes in carbon or fiber filter media, which are not likely in the near future, the radial design has potential for increased carbon weight and increased filtration area for an equal total volume of the container.

Both of these effects, although not large, will reduce pressure drop and increase capacity. In addition, the radial design, for a face mounted canister, has potential for placing the inlet valve, seat and mounting mechanism within the "donut hole" of the container (See Figure One). This should allow reduction of the dead space and/or improve "plumbing" within the facepiece. The canister can also be mounted closer to the head thus reducing torque and potential for breaking the face seal.

For larger filters mounted on the body and requiring blower assistance, the stacked radial design used with Modular Collective Protection Equipment (MCPE) should be investigated.

Figure One: Radial Canister



In addition to the features noted in Figure One, this approach may permit the motor/blower assembly to be mounted within the "donut" cavity as is the case with the MCPE. Construction features could readily allow for changing either or both filters, as well as easy substitution of new and/or alternate filters to address new or surprise threats. The approach also offers potential for attaching filters, which would operate in parallel with the original filter to reduce pressure drop or velocity. This would achieve increased protection and comfort or provide a "fresh" filter system. Energy added to the inlet from the motor/blower would also reduce the relative humidity of the air and assist in preventing fogging of the lenses.

The recently developed immobilized bed technology should be exploited. It offers the potential for molding adsorbent beds into useful shapes not readily achieved in standard axial and radial flow canisters. This may allow development of filters requiring less space which are more readily mounted in or on different body locations. Relative to the sorbent aspects discussed above, this technology would allow fabrication of sorbents and/or reactants of differing particle sizes, density, hardness, etc. in varying proportions to achieve improvements in agent vapor removal and bed dynamics (i.e. perhaps lower pressure drop) that cannot now be readily accomplished in a single packed bed. Immobilization may also provide sufficient increase in ruggedness to allow reducing the size/thickness or complete elimination of some canister components resulting in reduced bulk and weight. The immobilized bed technology may also be applied to standard beds, particularly radial beds, which are difficult to fill uniformly and achieve a proper packing density to prevent bed settling.

4.3 Logistics Considerations
Written By Captain June Sellers

Logistics should not drive the selection of a design for respiratory protection, but it will always be a major factor in any trade-off analysis. Any future design for a protective mask must be assessed for its impact on the logistics system. Increased burden due to logistics should be kept to a minimum (i.e. maximum use of common parts, modularity in design). An early determination must be made that an increased logistical burden will be outweighed by the enhanced capabilities provided by the new design so that adjustments in the logistical system can be initiated to accommodate it.

4.4 Human Factors Concerns
Written By Mr. Peter Paicopolis

The future helmet/mask system is being required to provide protection from multiple threats (i.e. ballistics, chemical and biological, directed energy, nuclear flash) and interface with increasingly sophisticated weapons systems. In the past, significant human factors problems have resulted from the interface between military protective masks and many weapons and equipment. These interface problems have degraded soldier performance. To avoid or minimize performance degradation and to ensure proper interface with weapons systems, systems integration may be the most important aspect of design and development of the next generation helmet/mask system.

Examples of interface problems which may be examined and which could be avoided or minimized through appropriate human factors analysis and systems integration are:

1. Incompatibility with optical and imaging vision systems used for day or night surveillance, target acquisition, and weapon fire control. Improper eye relief and brow pad interface reduces sight field of view which causes degradation in system performance.

2. Reduction in earcup hearing protection and communications capability (reduction in noise attenuation) due to the breakage of the helmet earcup seal by the protective hood.

3. Incompatibility of the mask suspension and helmet suspension resulting in pressure points or "hot spots" on the wearers head.

4. A different cheek interface with the M16 rifle requiring additional training to shoot while wearing a mask.

Two approaches to the design of a new helmet and mask system are under consideration to solve the interface problems, SIPE, and RESPO 21 programs.

The System Integrated Protective Ensemble (SIPE) program proposes to integrate the helmet/mask and also incorporate future weapons sighting and fire control information on the mask visor lens.

Because the mask will be integrated into the helmet and the weapons sighting information will be displayed the mask visor lens and interfaces along with resulting problems described above will be eliminated as follows:

- The weapons sighting will be on the mask/visor lens eliminating (1) above.

- The shell of the helmet will replace the protective hood for the head area, eliminating a requirement for a separate mask suspension; consequently, (3) above will be eliminated.

- Plans to incorporate weapons that allow a shoot from the hip capability, eliminate the cheek interface problems described in (4) above.

While this approach proposes the complete elimination of these interfaces and subsequent problems, the approach has a high degree of technical risk. Obtaining adequate face/head seals, motorblower/filtration dependency, the increased sophistication of the display system, are all significant technical barriers. Additionally, weight may increase along with greater soldier performance and training requirements.

The second approach RESPO 21, while yet to be completely defined, is currently planned to be a mask designed to function independently of the helmet without the incorporation of the weapons sighting system on the mask lens. Consequently, the interfaces described in 1-4 above will remain. RESPO 21 must seek to minimize the problems created by these interface problems.

Additionally, both the above approaches must address other non-compatibility interface problems which are inherent in masks:

1. Difficulty with unaided communication due to speech attenuation and distortion by the mask.

2. Loss of peripheral vision due to the shape and placement of the mask lens and the structure of the mask.

3. Respiratory fatigue due to mask breathing resistance and deadspace.

The soldier-machine problems touched on briefly here can and should be addressed through human factors systems analysis and integration wherein consideration is given to the performance of the soldier and his equipment as a system. This can only be accomplished through high weighting of system design and through prototype evaluation at the earliest possible phase of system development along with operational and development testing.

4.5 Materials Concepts
Written By Dr. Gary W. Good

The materials used to construct the Individual Protection Ensemble (IPE) mask and helmet will continue to be chemical/polymer mixtures and composite structures. The military use requirements in pounds per year are too small to motivate private industry to develop specific polymers and chemicals with the intrinsic properties required to satisfy military applications. The military designers and engineers must combine the different chemicals and polymers that are available from commercial sources or combine the materials in macroscopic arrangements in composite structures and layered structures to produce "compounded mixtures which have the desired properties.

The creation of compounded mixtures and composite structures is a science/art requiring experienced people. Most companies which produce parts made from polymers have at least one individual whose responsibility is to determine the chemical and polymer formulation of the materials. These formulations may have more than twenty ingredients selected from tens of thousands of possible ingredients. For all practical purposes, there are infinite combinations of an infinite number of ingredients. The cost effective creation of the mixtures and structures requires a theoretical understanding of the materials, experimental design methodologies, response surface methodologies, and property balancing techniques such as the Desirability Methodology.

One of the main difficulties is the cost effective replacement of existing materials and structures with new materials and structures. This may be a simple incremental improvement driven by cost, or the ability of a new material or structure to provide a major performance enhancement to the helmet or mask. Very seldom is there a surprise, however. There are usually one or two years of advance discussion within the materials community about a new material or process prior to it becoming commercially available. This lead time should allow the developers and engineers sufficient time to create contingency plans from the insertion of the technology into the mask.

Based on the discussions in the conference, the optical requirements can currently be met by a structure consisting of polycarbonate based polymer and an inorganic film deposited by means of a plasma process. The face part of the mask should be an elastomer to conform to facial sizes and structures. If the face part is sufficiently distant from an individual's face, then and only then, can a rigid or semi-rigid polymer satisfy the requirements.

It is very difficult to decontaminate an elastomer material. There is a finite concentration gradient within an elastomeric material which is greater than the accepted contamination levels.

Butyl Rubber, the most impermeable elastomeric material, must be boiled to be decontaminated. A feasible solution to this problem is a thin disposable covering to the mask which can readily be attached to the mask and be discarded after use.

Over the next ten years, there should be some significant advances in the ability of polymers to conduct electrical and thermal energy and systems which convert energy from one form to another, for example, heat to electrical energy. This of course is of major interest in R&D activities.

4.6 New Technologies
Written By Dr. Arthur T. Johnson

Discussions concerning application of new technology to mask design and fabrication quickly narrow to considerations of new materials. There is no doubt that materials are important in mask designs. Concepts and component technologies which could not be practically realized years ago are deserving new consideration because materials technology has progressed greatly. However, ideas and concepts which were not deemed possible, and were discarded before concept formulation, are now possible because of new technologies not involving materials.

If there is one area where the United States has a clear technological battlefield edge, it is in sensors and data processing. Advances in sensor technology have made possible biosensors, miniature transducers, and inherently digital measurements. Combining these inputs with miniature computers and advanced data processing techniques in expert systems, pattern recognition, and computerized tomography can make available the most well-informed and best equipped soldier in the world.

Information is power. Information about the environment, location of other units, and battlefield probabilities can let the soldier make better decisions, act more responsibly, and anticipate future circumstances leading to improved effectiveness. Sensors for basic weather data, coupled with computer programming, can predict weather conditions. Biosensors can provide CB threat information and even be used to advise on proper CB posture to optimize multiple responses to mask use, canister life, battlefield movement, and collective protection. Sensitive transducers will probably be required to give advanced warning of approaching enemy soldiers, vehicles, or aircraft, especially if a soldier's senses have been isolated from the environment by the protective gear. Communications enhancements can be made by computer processing of vocal information before it is amplified and transmitted.

Why hasn't the information age made an impact on mask design? Surely there could be logistical support problems, but these cannot be the full reason. Perhaps, like the United States automobile manufacturers of the 1970's, development structure for masks does not accommodate easily to the incorporation of completely new technologies. Whatever the reason, the mask of the future should be integrated, not only physically into other protective components, but also into a capable mobile information system serving the individual soldier and collectively serving the reconnaissance needs of units both small and large.

New technology must be incorporated in the design process as well. Advances in modelling and computer aided design have been slow to be applied to design of modern masks. One possible reason for this is the complex nature of the many interfaces

which the mask makes with its surroundings. The human head is the site of the largest sensory input required for human action. The mask interferes with most of this sensory input. In addition, the chemical/biological threat is not completely defined. The mask must nevertheless provide protection. Perhaps because of this complexity, modelling technology has not been developed sufficiently to allow easy estimation of design tradeoffs. Not many other products are being designed at present based on knowledge obtained during the 1940's and 1950's anecdotal instances and "seat-off-the-pants" estimates. New technology must pervade the entire respirator process from conception through design through fabrication, and, finally, testing.

4.7 Predictive Modeling
Written By Dr. Ralph F. Goldman

Introduction:

Predictive modelling should play a major role in evaluating human-environment-IPE mission performance interactions. The ability to vary a single parameter at a time, choosing environmental or individual protective ensemble item characteristics at will, and receive a "best possible estimate" of the effects on task performance is a very powerful tool in RDT&E, as well as in the analysis of tactics, projecting casualty levels and the like. Predictive modelling is particularly useful in projecting along the three lower levels of analysis including:

1. Physical studies of materials or mechanical systems.

2. Biophysical studies of protective ensembles and their associated components (i.e. mask, hood, microclimate conditioners, etc, involving anthropometric models and or physical/physiological and psychological human response models).

3. Small scale human subject "validation" studies to test the goodness of fit between predicted effects and human response.

Practical Considerations:

There are some practical aspects which should be considered by modelers in order for a model to have utility. Models should do the following:

1. Be "rational" as much as possible.

2. Be quantitative rather than simply relational.

3. Be based on measurable input parameters.

4. Avoid unmeasurable components within the model.

5. Provide measurable outputs.

6. Be designed in a building block frame, with "small bite" studies or elements added sequentially.

7. Be validated against a prior hypothesis, not by fitting data post-collection, before release for discussion.

Model Building

There are a series of steps to be followed in model

building. Suggestions for some of these, and their sequencing is outlined as follows:

1. Develop a hypothesis; theoretical or postulated.

2. Use a systems analysis approach. (i.e.: Input---Transfer Function---Output)

   where the Transfer Function is assumed to explain most of the Input/Output relationship and the "remainder term" represents either system "noise", interaction terms, or failure of the initial hypothesis.

3. Build the model. (i.e. Develop the algorithm = "Transform Function" = "Transform" for Input/Output, using whatever data one can find or appropriate assumptions).

4. Test the model.

5. Refer to step three and repeat until the "remainder term" is as small as possible and the Input/Output relationship is meaningful (n^{-2}>0.7)

6. Choose one or more "adequate forcing functions" and a control input.
   (i.e. test only input conditions which, the newly developed model suggests, provides measurable, meaningful differences in output between the "control" item response and the test item response to that forcing function).

7. Get another investigator to run the "validation study".

8. If the results validate the model, advance to the next element to be modeled. If not, go back to step three.

   Appendix B contains a summary of predictive model types.

4.8 Respirator Communications
Written By Dr. Ronald A. Weiss

Communication is a very important aspect of military activity. At present nearly one in fifteen people is involved with formally transmitting messages by radio, telephone or some other electronic means of communication. Even at the squad or detail level, verbal orders must be given and understood to carry out assigned missions. To attempt to provide this verbal communication directly or through a radio/telephone has been very difficult with a military NBC respirator. The following considerations should be included in future respirator designs to improve communication capabilities.

Rapid Speech Intelligibility Index (RASTI), a method of analyzing speech clarity and intelligibility, should have a value of at least 0.85 on a scale of 0.1 to 1.0. While a value of 1.0 is considered perfect intelligible, any value above .80 is considered having excellent intelligibility. However, both the vowel and consonant portions of speech should have this same level of intelligibility. Current mask designs do not have this level of intelligibility as an average value nor are the vowels and consonants equally weighted.

The pure tone frequency range of any voicemitter or amplifier should be responsive up to 12,000 Hertz frequency to provide harmonic shading to the consonants for clarity. The pure tone frequency response should also be designed to enhance some specific frequencies which tend to be distorted due to the frequency characteristics of military equipment operation. For example some current voicemitter designs will cause attenuation of sound at a specific frequency for a number of reasons (mounting, vibration stiffness of the sounding plate, nosecup shape, etc.). If the firing of a rifle nearby also has the same inherent frequency in its major component, it will be very difficult to hear any consonants that depend on that frequency for transmission.

The nose cup and mask materials should take into consideration their sound damping and reverberation characteristics to try and improve speech. Any material or design with a reverberation decay time of 0.2 milliseconds will cause difficulty in communication understanding. The voicemitter should be mounted in front of the mouth at a distance not to exceed 25 millimeters for best transmission. The nose cup should be shaped like a megaphone if possible to aim the sound transmission at the voicemitter. The voicemitter vibration plate should have a frequency response sufficient to accommodate a .3 millisecond pause (as seen between syllables in words of three or more syllables) and that this pause does not effect transmission immediately after the pause.

We are currently using a 15 percent drop in sound pressure level as the criteria for determining the distance that sound

will travel from a mask. This represents a drop of 3 dB from the original sound pressure level at the mouth. When the listener, either person or microphone, is placed directly in front of the masked speaker in a background noise of 60 dB, there should be a maximum of 3 dB sound reduction at a distance of five meters. When the masked speaker is shouting in a background noise of 85 dB he should be heard at the same distance with an attenuation of only 3 dB of the original speech sound pressure level. When coupling to a radio/telephone, etc., the attenuation should not exceed 10 dB at a 20 centimeter distance.

Moisture is a critical problem in the sounding plate of the voicemitter. If the voicemitter is dampened or absorbs only 5 grams of water it can reduce speech intelligibility by as much as 30-40 percent.

Hearing through the hood or other head covering must be considered to close the loop on communication capability with a respirator. Much work must be done in this area to define the attenuation characteristics of materials, the potential improvements with masking of one ear to delay signals to the brain and thereby improve the signal detection, etc.

Much work is being done on the use of various types of speech amplifiers for masks. Types of approaches being studied include the following:

1. Units to clip over voicemitter to amplify the transmitted sound.

2. Screw in amplifiers replacing voicemitters.

3. Bone conducting microphones that attach to the seal of the mask and come in contact with the bones of the skull for transmission and ear transceivers which fit into the ear canal using standard or custom fit molds and have the capability of sending or receiving messages through the ear canal.

All of these concepts should be given consideration for future designs.

Two major limitations found to-date are that the voicemitter and exhalation valve should not be combined because the exhalation valve acts as a high bypass filter sharply limiting sound production and direction. The other is that an improperly sized mask dramatically reduces communication capability. For example, a large sized mask on a medium face will give an adequate protection factor seal but lower communication capability over that observed with a medium sized mask on the same face.

4.9 Respirator Exhalation Assistance
Written by Dr. Ronald A. Weiss

Respirators designed to-date, both domestic and foreign, have been hampered with a problem of increased resistance during the exhalation portion of each breath. This resistance is evidenced by the wearer feeling the exhaled air escaping from the peripheral seal of the mask during moderate to heavy work loads. Even at relatively light workloads and rest, the wearer will sometimes hear the mask exhalation valve pop due to the extra resistance and usually results in a popping noise when broken at each breath.

Another factor in the physiology of exhalation is the fact that the exhalation of each breath at rest is passive. For example, the chest and diaphragm muscle do not contract or expand energy to push the air out of the lung. During heavy exercise, however, the seldom used chest muscles will actually contract forcing a larger volume of air out of the lungs. Because these exhalation muscles are seldom used, they have a tendency to fatigue very easily and limit respiratory capability.

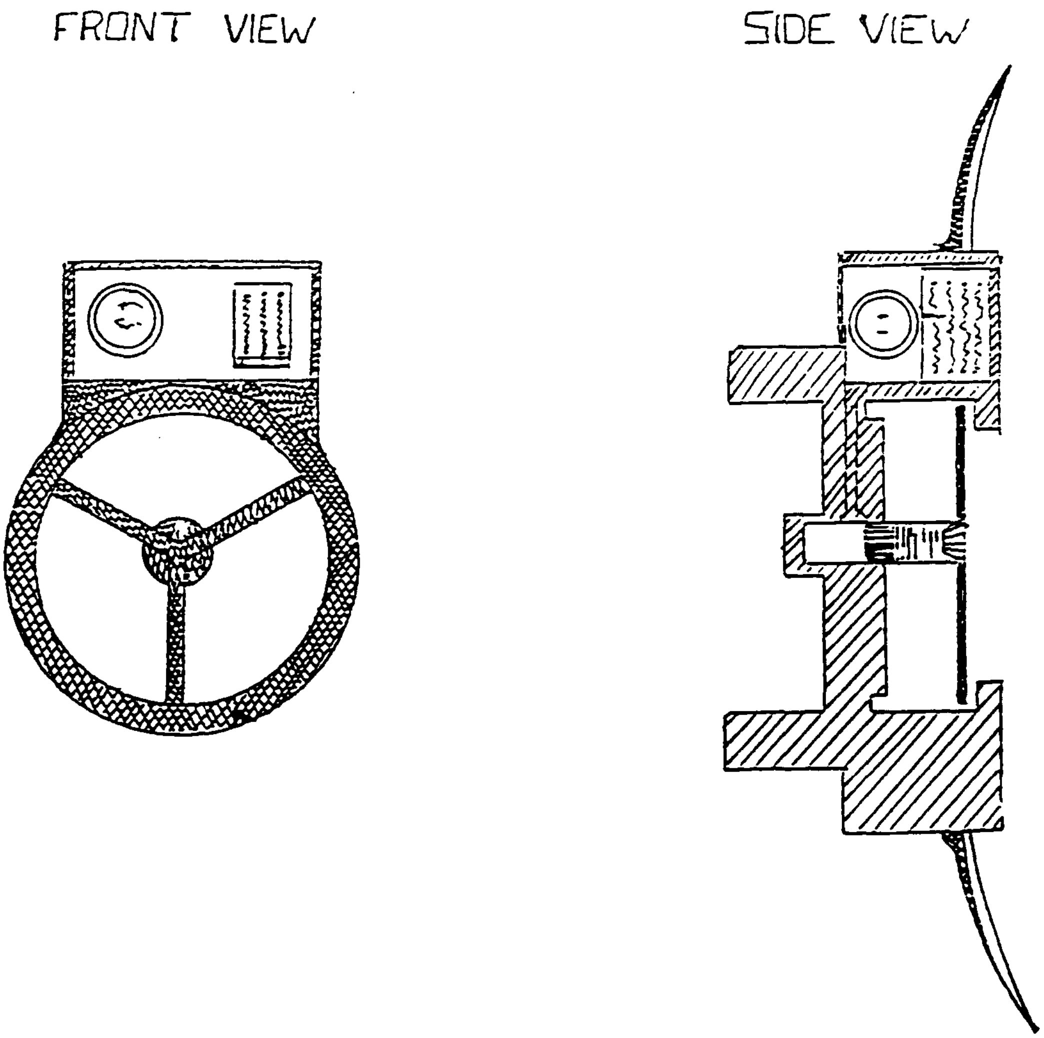
As a result of these inherent limitations with mask exhalation, it is proposed to radically change the method of respirator breathing assistance. The standard approach in mask design has been to use a blower on the inlet side of the mask to overcome the resistance of the inlet filter. It is proposed that, instead, a blower is attached to the outlet side of the respirator, or in the event a blower assist capability is not used, provide a microprocessor controlled enhancement to the outlet valve to amplify its ability to open and thereby reduce exhalation resistance.

Figure Two provides a side and front view of a conceptual valve connected to a solenoid type arrangement. Mounted in the solenoid at the surface of the inner mask side of the valve is a pressure or carbon dioxide sensor. As the transducer detects a change in pressure beyond a set minimum limit or an increase in carbon dioxide in the mask, this change is used to pull the solenoid back into its coil thereby opening the space between the valve and its seat. With a built in feedback circuit, this unit can be controlled to move the valve only the amount required for breathing comfort and limit the need for power required to operate it.

Immediately above or below the outlet valve in a protective housing, as part of the valve seat, a cavity containing a wristwatch type battery and the electronic printed circuit board will be mounted to make the concept work (as seen on the attached sheet).

The cost of the unit might be reduced by using a capacitor as a pressure transducer rather than a formally designed pressure

Figure Two: Powered Exhalation Valve



transducer. Such an approach is used for an oil pressure sensor in automobiles and is relatively cheap; approximately $2.50.

A drawback to this approach should be noted, however. If the motor blower is attached on the outlet side of the mask and runs continuously, masks with a poor facial or nosecup peripheral seal may have an inward leakage at those locations due to a higher flow rate than the person is breathing. If a negative pressure mask concept is used, however, the valve assisting device would not have that inherent limitation.

4.10 Systems Compatibility
Written By Richard W. Brletich

With the development of heads-up displays, helmet mounted displays, guided weapon systems, and visual enhancement systems, the need to get the head and eyes close to the optical or weapon system has become critical. Current night vision systems require the user to be within 18 millimeters of the eye's exit pupil in order to achieve the full 40 degree field of view. The M16 rifle and M24 and M40 sniper systems require the user to achieve a solid spot weld between their cheek and stock in order to properly sight the weapon.

Existing chemical protective masks require manipulation of the system to achieve an interface with the system. Some items cannot interface with the respiratory system without degrading performance to an unacceptable level. The recently developed M43 protective mask, with its close fitting lenses and conformal facepiece, can achieve compatibility with existing systems. As a near term solution, CRDEC is developing a mask that combines the compatibility of the M43 with the protection levels of the M40 system.

The future development of respiratory protective systems needs to address the compatibility of the respirator with the system that it must interface with. One possible approach is the development of a display system integrated into the respirator/helmet system. This approach, however, does not address the compatibility with existing sights and optical systems. Both situations must be addressed. A better solution may be attaching the integrated sighting system to the helmet and designing the respiratory/ballistic system to allow interface with systems in a conventional manner.

Whatever approach is finally decided upon, the ability to interface with all Army systems needs to be addressed.

4.11 The Soldier is a System
Written By Ms. Carol J. Fitzgerald

It is precisely because the soldier is a person that we must consider him/her as a system. The soldier is, in fact, the single most important asset which the Army has. It is not until we consider all the elements of the soldier system simultaneously (i.e. clothing and individual protection equipment, communications equipment, weapons and ammunition-essentially everything a soldier wears or carries) that we can begin to realize the synergism of soldier, equipment, and operational capabilities that the Army needs in order to improve its warfighting capability. The systems approach to the soldier will facilitate the striking of a balance of performance capabilities and protection, whether it be protection from the environment or from enemy threats. The difficulty in implementing such a philosophy is that beyond the technical and technological limitations lies the Army's R&D structure whereby soldier oriented R&D is conducted by several centers and labs. Soldier type items are generally developed against individual requirements. Although they are individually well designed and provide excellent capabilities when used simultaneously, they provide optimal capabilities to the soldier as well as contribute to performance degradation.

There are a number of benefits which are not unrealistic to achieve by using a systems approach. These include improved survivability against multiple threats, and improved performance capabilities as a result of soldier-to-soldier communications, weapons interface/linkage with headgear, and reduction in total weight and bulk to minimize the functional redundancies which would prevail if the soldier was to wear/carry all the individual items whose capabilities could be provided within an integrated individual fighting system.

Specifically relative to head protection, whether it be respiratory protection, ballistic protection, laser protection, weapons interface, communications capabilities, etc., the development of optimal solutions can best be facilitated by considering them simultaneously. This will allow for analysis of how the means for providing the capabilities not only interface and interplay with one another, but also with the wearer so as to minimize the cost to the wearer. These capabilities, whether they be operationally or threat oriented will always come at some cost to the soldier. The systems approach to developing a modular headgear system, as well as the entire head-to-toe individual fighting system, will provide the mechanism and philosophy by which to minimize the cost, thereby achieving optimal operational effectiveness of the soldier.

Taking this approach one step further, the headgear can be better developed considering as part the larger soldier system. For example, a headgear system which is powered when considered as part of the larger system will allow for the configuration of

the power source in a location other than on the head to minimize the cost (i.e. metabolic cost, comfort, compatibility with other equipment, weight, center of gravity, etc). In addition, an individual fighting system which is microclimate cooled provides the opportunity to share power sources, filters, and cooling sources.

The time has come to stop stovetop development and to make strides to consider the soldier as a system in order to provide operational improvements so readily needed by the Army. It is precisely because the soldier is a person that the Army must embrace such an approach.

5.0 CONCEPT ADVANTAGES/DISADVANTAGES

CRDEC has developed three initial respirator concepts in order to facilitate the development of RESPO 21. The three concepts were introduced in order to stimulate discussion regarding the features of each concept. These respirator concepts are described in section 2.1 of this conference proceeding. A discussion of the merits and shortcomings of each of the concepts was conducted among the workshop participants. A summary of the outcome of this discussion follows. Immediately following the concept advantages/disadvantages is a list of potential fixes for each of the concepts as provided by the conference participants.

Concept 1 - Soft Shell Designation (Figure Three)

Advantages

- Light weight
- Relatively inexpensive
- Minimum bulk
- Flat or near flat optics allow good optical interface
- Minimum interference with the helmet, conformal
- No power requirement
- Low dead space
- Potentially disposable, requiring no decontamination or maintenance
- Improved speech
- Utilizes absorptive materials which combat moisture

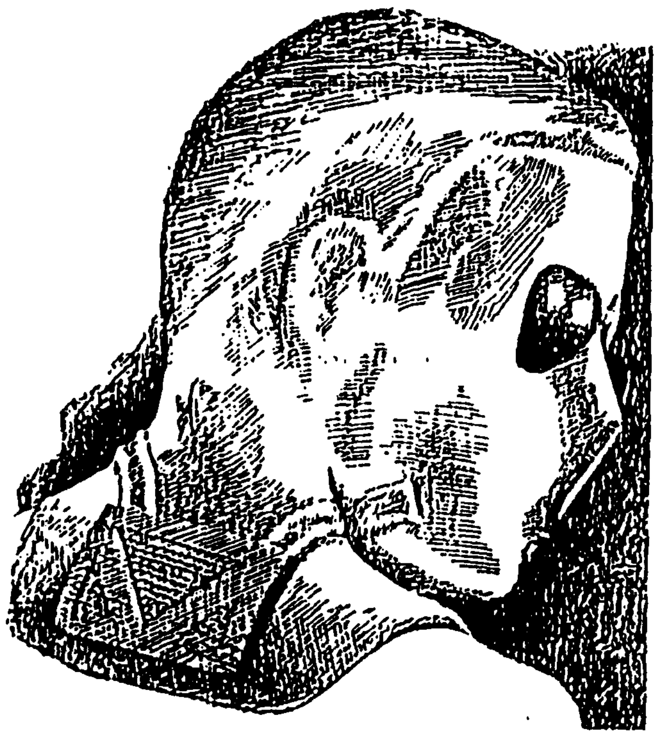
Disadvantages

- Sizing problems
- Limited durability
- Auditory impairment, ear cup seal impaired
- Unproven/unevaluated seal system
- Imposes a greater logistics burden
- Potentially requires individual issue (i.e. prescription corrective lenses)

Figure Three

RESPO 21

CONCEPT #1



DESIGNATION: Softshell

COMPONENT TECHNOLOGIES:

POWER SUPPLY: None (Optional Blower)

FACEPIECE DESIGN: Conformal TPE Laminated Foam

AGENT PROCESSING: Low Profile, High Surface Area

COOLING: Heat/Moisture Absorbing Materials

RESPIRATORY: Low Dead Space Volume

OPTICS: Near Flat Optics (Laser or Correction Optional)

COMMUNICATIONS: Thin Film (Optional Electronics)

SEAL: Low Durometer Foam Liners

SPECIAL FEATURES: Disposable, Lightweight, Conformal

- Filter concepts and locations ill defined
- Cooling concept untested
- No ventilation exists in hood, therefore, may contribute to heat stress
- Potentially limited environments for use due to stiffening of materials at cold temperatures and potential for frost bite resulting from conformal fit
- Minimal improvement in peripheral vision
- Moisture absorbing materials may not be available, offering potential for moisture accumulation which may lead to bacterial problems
- Because of close fit, beard growth will also contribute to bacterial problems
- Neck seal may contribute to claustrophobia

Potential Improvements

- Zipper for ventilation
- Pockets for lenses (i.e. Contain laser protection or corrective prescription lenses)
- Utilize immobilized carbon bed technology
- Mouth inflatable seal
- Mouth suction seal
- Incorporate bifocal lenses
- Incorporate drinking capability

Concept Two Semi-Rigid Designation (Figure Four)

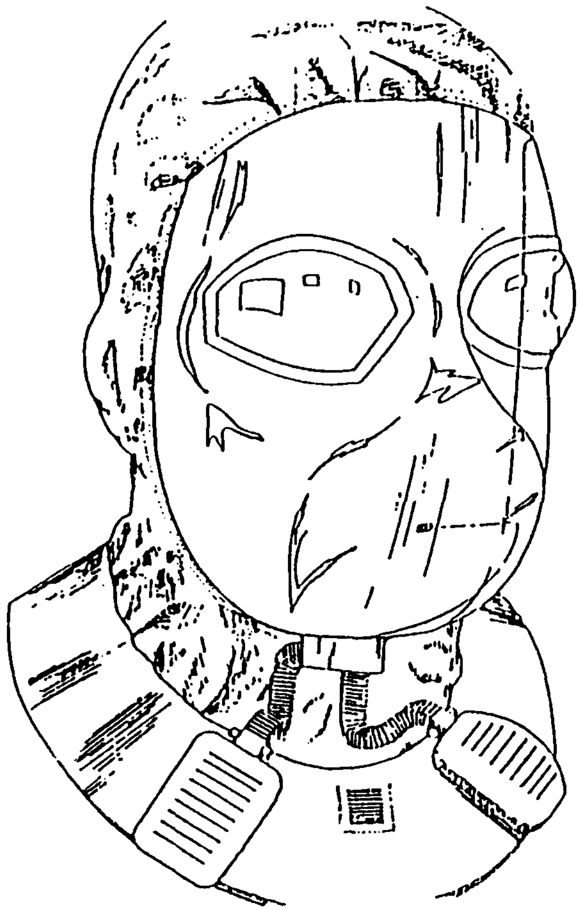
Advantages

- Limited external power required
- Potentially optimum optics/optical interfaces
- Improved communication via voice face-to-face and internal radio
- Potential for external radio communication

Figure Four

RESPO 21

CONCEPT #2



DESIGNATION: Semi-Rigid

COMPONENT TECHNOLOGIES:

POWER SUPPLY: Commo. Only (Optional Blower)

FACEPIECE DESIGN: Transparent Thermoset Copolymer

AGENT PROCESSING: Mobile Filter Cartridges

COOLING: Pre-Alert Venting/Removable Hood (Blower Op)

RESPIRATORY: Pre-Alert Low Resistance Filter/Valves

OPTICS: XM44 Type Lenses (Laser or Corrective Insert)

COMMUNICATIONS: Voice Amplification System

SEAL: Unimolded Low Durometer Bladder

SPECIAL FEATURES: Transparent, Self Adaptable

Potential for Replaceable Fluorocarbon Coating

- Proven cooling mechanisms
- Option for "no hood" operations
- Proven seal configuration
- Improved soldier recognition
- Transparency is an optical plus as the soldier can communicate via facial expressions
- Several filter location options
- Filter/Non-filter options (i.e. use non-filter option in pre-alert)
- Off-the-face filter allows improvement in the following:
  - Filtration efficiency
  - Agent capacity
  - Breathing resistance
- Improved potential for filter changes during attack
- No nosecup
- Dual path - increased area

<u>Disadvantages</u>

- "Battery" logistics
- Increased leak source in filter options/valving
- Expensive to produce for the following reasons:
  - Transparent face blank materials are expensive
  - Communications equipment is required and such equipment is costly
  - Initial cost is higher because of molds
- May require a double coating to make face blank agent impermeable
- Hoses required
- Durability may be limited
- Potentially requires individual issue, therefore, need spares
- Integration with blowers may be complicated with multiple filters which are mobile

- o Interferes with ear cup seal, consequently impairing normal hearing
- o Glare
- o Greenhouse effect in sunlight
- o Discoloration of transparent materials
- o Requires availability of Chemical Agent Detector due to decreased olfactory cues
- o Sizing problems exist
- o Increased risk of leaks due to seal breakage
- o Lack of standard NATO threads

Potential Improvements

- o Incorporate filter system into the suit
- o Place exhalation ports close to mouth

Concept Three- Hard Shell (Modular)
(Figure Five)

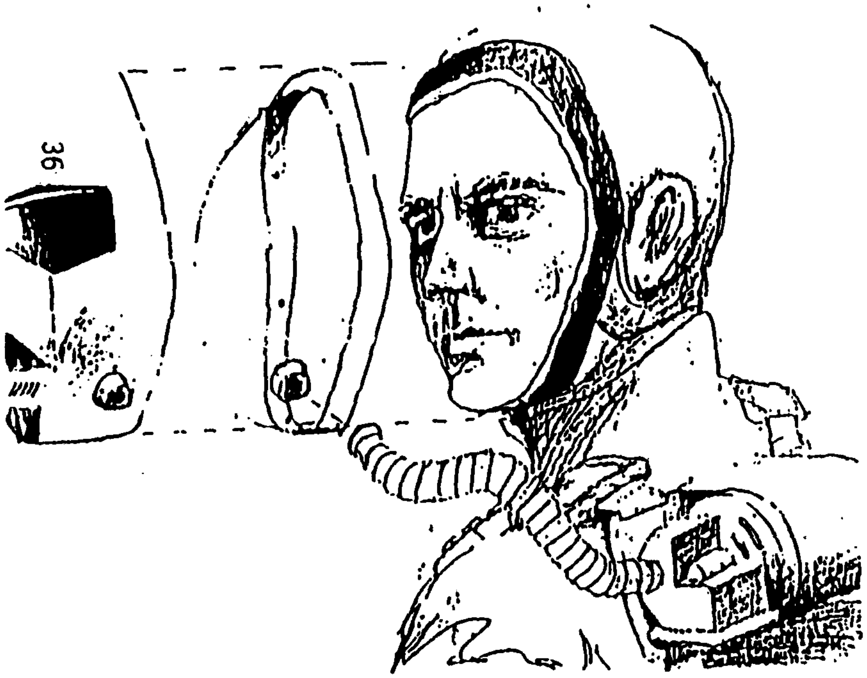
Advantages

- o Improved ballistics protection
- o Lower breathing resistance
- o Convective air provides:
    - Improved cooling in warm/hot weather (i.e. blown mode provides forced air convection cooling)
    - Reduced fogging
- o Permits increased filtration efficiency and agent capacity if required
- o Modular construction (multiple face plates)
    - Claustrophobia reduced when face plate is off in non-alert situations
    - Medical applications (i.e. simply remove face plates to measure vital signs in a casualty situation)
    - Maximum comfort in non-alert situation
    - Provides multi-threat protection (i.e. laser protection, blast protection, etc.)
    - Potential for improved soldier recognition

Figure Five

RESPO 21

CONCEPT #3



DESIGNATION: Hardshell (Modular)

COMPONENT TECHNOLOGIES:

POWER SUPPLY: Lithium Thionyl Chloride

FACEPIECE DESIGN: Liquid Crystal or Polycarbonate

AGENT PROCESSING: Blower (Potential Electrostatics)

COOLING: Forced Air Convection

RESPIRATORY: Breathing Assist, Auto. Valving

OPTICS: B-LPS Design or Full Face Bubble

COMMUNICATIONS: Infrared (IR) or Local Network

SEAL: Pneumatic (Encapsulated Gel Back-up)

SPECIAL FEATURES: Modular Facepiece Design

Potential for Limited Fragment Protection

- Improved communication
- Potential pressure demand feature
- Interfaces well with *SIPE* helmet
- Improved seal; good seals result between two hard surfaces
- Best peripheral field of the three concepts
- Best respiratory protection of the three concepts
- Adaptable to vehicle collective protection

<u>Disadvantages</u>

- Optical coupling
- Large battery pack required for out-of-vehicle operations
- Rigid face piece may limit compatibility with various helmet systems
- Potentially incompatible with sighting systems
- Increased leak sources in the various seals
- May require added heat in cold weather operations to prevent frost bite
- Potential fit problems with rigid face blank
- Increased weight
- Increased bulk
- Hoses required
- Probably requires microclimate cooling
- Electromagnetic Interference (EMI) signature
- Sizing problems
- Logistics problems
- Costly to produce

<u>Potential Improvements</u>

- Rigid face plate could be made to give optical coupling
- Make seal on chin soft

o Replace rigid faceplate with concept two faceplate

In an effort to summarize the concept critique, a table of advantages and disadvantages follows. (See Table One) In Table One, the minus indicates that a feature is a disadvantage while the plus indicates that a feature is an advantage. The "0" represents a feature which is neither an advantage nor disadvantage.

For each feature listed as a disadvantage in Table One, a potential feature improvement is presented. The following list summarizes the potential improvements.

Potential Improvements

Concept 1 - Soft Shell Designation

o Consider utilization of seals used in Concepts 2 and 3

o Allow for adaptability to a blower unit

o Provide nourishment capability

o Consider ear covers made of semi-permeable materials

o Utilize mobile filters as used in Concept 2

o Investigate more durable materials/liners

o Consider adaptability to hardshell cover or apply to helmet

Concept 2 - Semi-Rigid Designation

o Provide nourishment capability

o Investigate more durable materials

o Consider adaptability to hardshell cover or apply to helmet

Concept 3 - Hard Shell (Modular)

o Apply careful design of the faceplate for maximum comfort/compatibility

o Allow for seal adjustments

o Design to allow for modularity in power subsystems

Another method of reducing the burden to the soldier is the incorporation of modular design characteristics which allow the soldier to adapt the mask to his specific needs. Some of the

Table One: Advantages and Disadvantages of the Respirator Concepts

Feature	Concept One	Concept Two	Concept Three
Protection/Seal	-	+	+
Cooling	-	+	+
Moisture Removal	-	+	+
Breathing Resistance	0	+	+
Dead Space	+	0	0
Nourishment	-	-	-
Weight/Bulk	+	0	-
Comfort	+	0	-
Field-of-View	0	+	-
Optical Compatibility	+	+	-
Speech	0	+	+
Hearing	-	0	0
Psychological	0	+	-
Sizing	-	0	-
Donning	-	0	0
Filter Location	-	+	0
Bacterial Concerns	-	0	0
Recognition	-	+	0
Durability	-	-	+
Environmental	-	0	0
Ballistic Protection	-	-	+
Laser Protection	0	0	+
Logistics	-	+	-
Power	+	0	-
Cost	+	0	-

features that can be made adaptable are:

- Seal/Sizing
- Optional Blower
- Moisture/Comfort Liners
- Inhalation/Exhalation Resistances
- Speech Amplifiers/Radio Connectors
- Filter Location
- Faceplate/Ballistics Cover
- Laser/Corrective Lenses

6.0 NEW CONCEPTS

In addition to the three concepts presented by CRDEC at the workshop, three new concepts were introduced by several of the attendees. These new concepts were presented by the following attendees:

- o Scavnicky/Paicopolis Mask Concept: Mr. John Scavnicky - U.S. Army Chemical Research, Development and Engineering Center (CRDEC) and Mr. Peter Paicopolis - U.S. Army Human Engineering Laboratory (HEL)

- o SIPE Mask Concept: Ms. Carol Fitzgerald - U.S. Army Natick Research Development and Engineering Center (NRDEC)

- o Johnson Mask Concept: Dr. Arthur Johnson - The University of Maryland College of Agriculture

Scavnicky/Paicopolis Mask Concept

This mask design features a swimmers type goggle. The mask design incorporates an eyecup seal with the frame of the goggle being attached to the facepiece of the mask. The facepiece around the goggle will be a flexible convolute. The goggle will have a temple strap attached at the frame of the goggle to allow for adjustments to accommodate anthropometric variations. A miniblower filter mounted on the mask will provide 1 L/min of filtered air for lens defogging. The oral/nasal cavity is independent of the optical compartment. Nosecup valves will not be required as inspired filtered air will flow directly into this cavity. The peripheral seal will be either an intern or conformable liquid seal such as silicone gel. The skull cap suspension system will be a lycra/charcoal material utilizing the Von Blucher technology. It can be used to create a vapor scavenging suspension system which will reduce the challenge to the peripheral seal.

In summary, the key features of this mask are:

- o Three sealing mechanisms including eyecup/oronasal, peripheral, and scavenging suspension

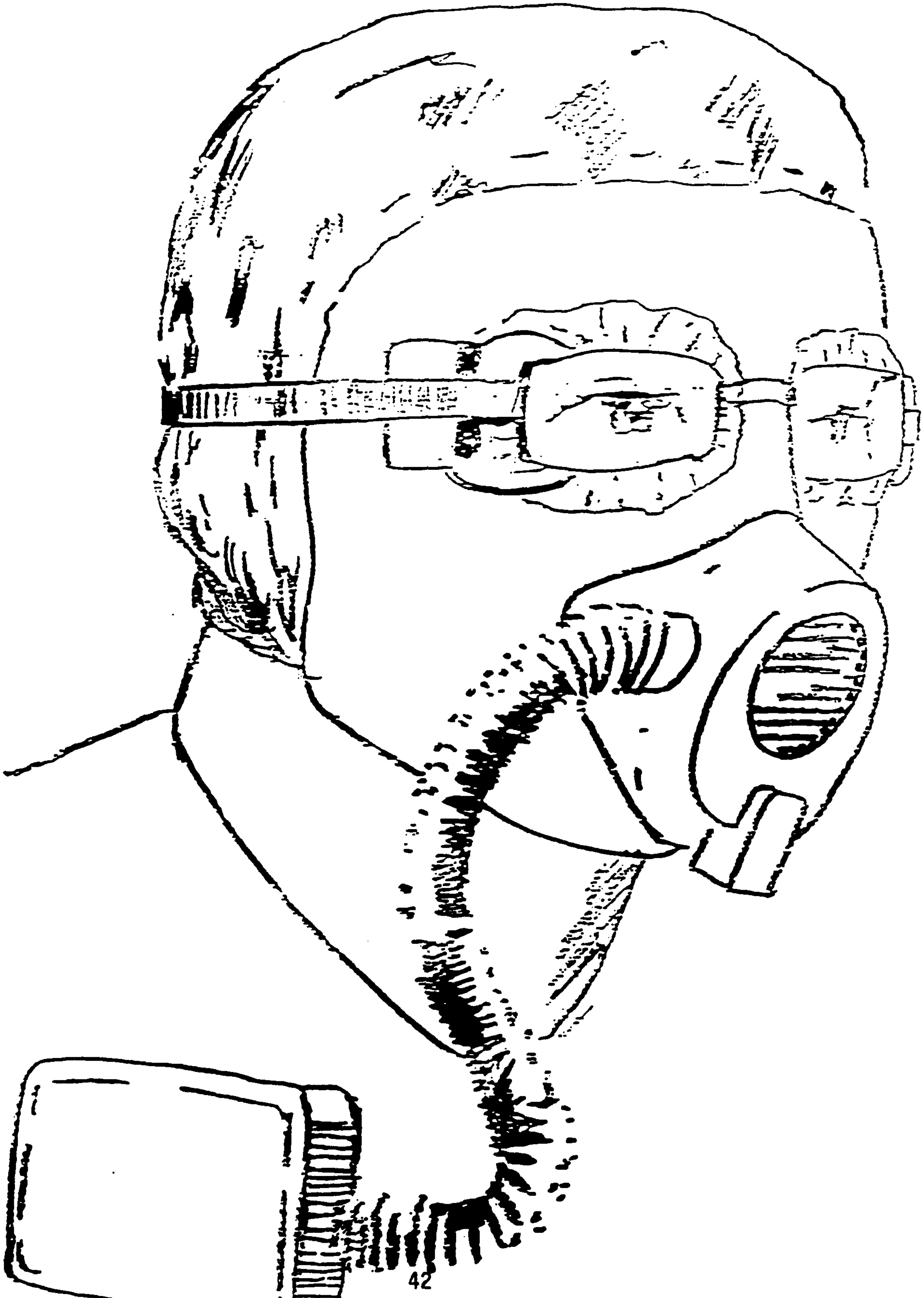
- o Close-in, adjustable optics, with a mini blower/filter defogging

- o Inspired air flow, directly into the oral nasal cavity

Figure Six contains an artists rendition of the Scavnicky/Paicopolis mask.

The key merit of this mask discussed by the group was that the concept improves many of the optical problems associated with the other mask concepts presented. In addition, the concept fits

Figure Six: Scaunicky/Paicopolis Concept



a broad group of wearers. This mask represents an evolutionary progression in the design.

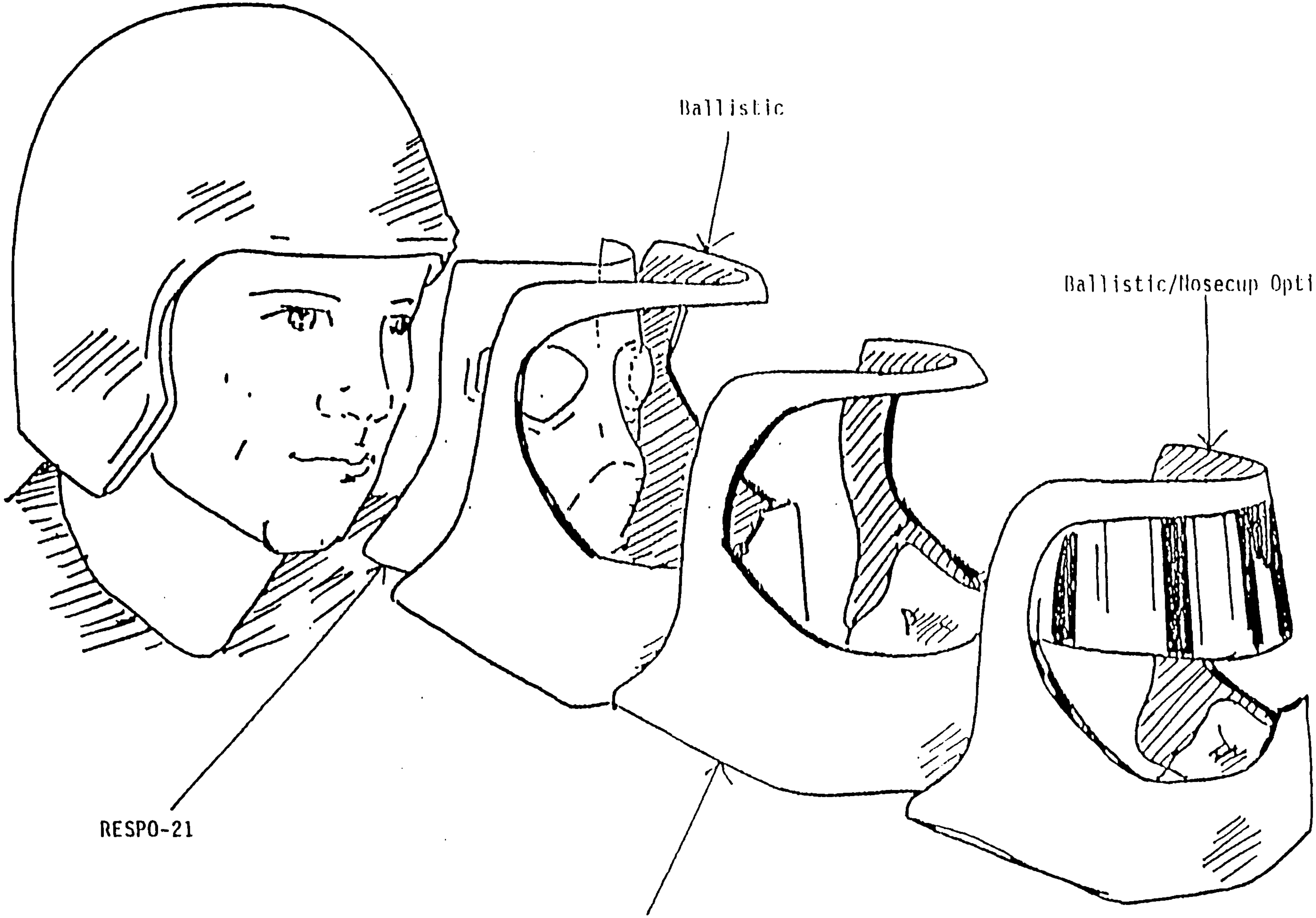
SIPE Mask Concept

The System Integrated Protective Ensemble (SIPE) mask concept, part of a joint design venture between NRDEC and CRDEC, seeks to provide integration between the mask and helmet. The design concept should incorporate multi-threat protection to include ballistic protection, laser protection, chemical/biological protection, and flame protection. Natick is currently pursuing an Advanced Technology Transfer Demonstrator, ATTD for FY90/91. An artist's rendition of this concept is found in Figures Seven and Eight.

Johnson Mask Concept

Dr. Arthur T. Johnson introduced a preliminary mask idea which incorporated a disposable, one-use mask. The mask would have limited protection capacity, but would be used for light to moderate threats for no more than 24 hours. The mask would be inexpensive and stocked in large numbers. The need to accommodate several mask sizes could perhaps be served by fabricating the face blank from a thermosetting moldable material which could be fitted to the individual wearer. Dr. Johnson indicated that he saw this mask as serving the vast majority of mask needs, and that other masks now being designed and already in the system would be considered to be specialty masks or extended capacity masks to be used when needed. This mask could also lend itself to a modular design by permitting add-on protection for more severe threats. If the most likely CB threat to be encountered is considerably less severe than the standards now being designed for, a basicly simple mask may pose the least logistical burden for the support systems.

Figure Seven: SIPE Integrated Concept



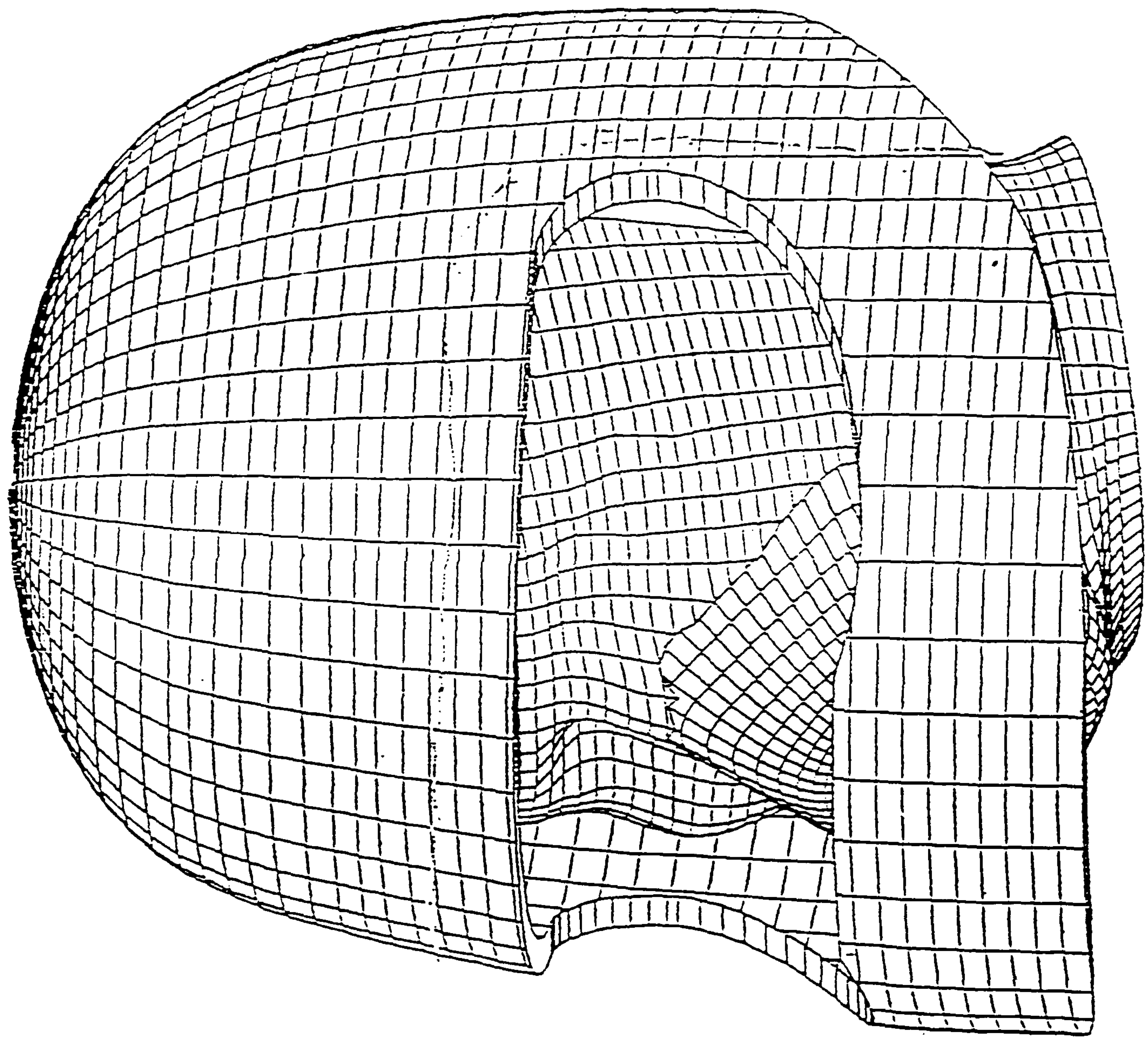


Figure Eight: SIPE Integrated Concept

7.0 FUTURE REQUIREMENTS TRADE OFF ANALYSIS

The development of RESPO 21 will involve numerous design decisions that will require tough choices. The design to meet one requirement could impose significant penalties in other areas. For example, the incorporation of heads-up displays or motor blower units for improved breathing resistance will impose a weight penalty upon the wearer and a logistical burden to the Army supply system. The added requirement of ballistic protection could increase weight and reduce the ability of the respirator to interface with weapon and optical systems.

Dr. Frank Shanty wrote the following description regarding the difficulty associated with the development of IPE equipment:

> "IPE imposes decrements to performance on the soldier (i.e. loss of vision, loss of ability to communicate, loss of dexterity, heat build-up and increased resistance to breathing). Together these individual decrements add up to what we call the total IPE burden. However, at present we cannot quantify what portion of the total burden is contributed by each of these separate elements. In other words, is the loss of vision responsible for 2 percent or 20 percent of the total loss of military effectiveness?"

A 100 percent solution to the mask design requirements may not be feasible. The "costs" to the 100 percent solution may make it undesirable. It was the consensus of the attendees that a 80 percent solution may be most feasible. Before any designs for RESPO 21 are finalized, a thorough evaluation of the ramifications of all decisions and requirements should be made. If not, critical design features could be ignored or decreased in effectiveness while unnecessary requirements and features are included. Current and anticipated future technologies will not allow the inclusion of all desired characteristics. Therefore, it is recommended that prior to Design Workshop Two, a preliminary trade-off analysis should be conducted.

8.0 CONCEPT JUSTIFICATION

In addition to determining the advantages and disadvantages of each of the three originally proposed concepts, the workshop attendees offered recommendations regarding operational uses for each concept. The recommendations offered were the following:

Concept One - Soft Shell Designation

Operational Uses:

- Covert operations/friendly forces support
- Civilian use
- Special forces
- Secret Service
- Collective protection shelter operations during entry/exit procedures

Concept Two - Semi-Rigid Designation

Operational Uses:

- All combat operations where adequate logistics support is available for batteries, filters, hoods, hoses, and communication devices
- Civilian friendly forces support

Concept Three - Hard Shell (Modular)

Operational Uses:

- All vehicles with auxiliary power and/or Collective Protection
- Collective Protection shelter operations
- Special purposes (i.e. EOD, Depot Operations, etc.)

The recommendations regarding concept operational uses served to justify whether any or all of the concepts should be further pursued. The attendees reached the consensus that none of the concepts should be rejected at this time. Furthermore, each of the three concepts should in fact be further pursued. Specifically, recommendations were made to produce concept prototypes. However, prior to pursuing the design prototypes, each of the designs need to be further defined and many of the

concepts' specific details have yet to be ironed out. Finally, it was recommended that the systems prototypes be developed prior to Design Workshop Two. This will give the participants of Design Workshop Two the opportunity to further critique the designs and offer subsequent recommendations regarding whether the concepts should be further pursued to the testing stages.

9.0 RECOMMENDATIONS/CONCLUSIONS

The Respiratory Protective System 21 (RESPO 21) program was initiated in order to replace the M40/42 protective mask series. Front end analysis has indicated that while maintaining the levels of protection offered by the M40/42 series, the RESPO 21 design should offer improvements in the areas of mission degradation and system integration. One of the key goals of the workshop was to utilize expert consultation to assure that the most advanced technologies are applied in the effort to achieve the improvements specified above.

Several recommendations from the 1988 Technology Workshop were re-evaluated. The participants of the 1989 Design Workshop concurred with these recommendations. The following is a summary of the recommendations of the 1988 Technology Workshop:

Recommendations

Agent Processing

- Initiate advanced filter design studies to include:
  - Low profile, easy replacement attachments
  - Polymeric housing
  - Immobilized bed technology
  - ASZ-TEDA implementation
- Conduct a feasibility study on electrically enhanced filtration
- Conduct a feasibility study on pre-filter humidity control systems
- Investigate reduced size specialty canister designs for improved performance adaptability
- Continue to establish database on new technologies

Cooling Systems

- Investigate custom high efficiency blower design
- Monitor microclimate cooling progress and allow for adaptation
- Investigate heat/moisture absorbing materials for hood/ suspension design
- Continue to establish a database on new technologies

Communications

- Continue assessment of amplified voicemitters

- Investigate hybrid (no power) voicemitter designs
- Revise communication standards to align with field problems (i.e. CANE studies)
- Continue to establish database on new technologies

Materials

- Investigate strippable coatings for silicone
- Investigate silicone copolymers as flexible optical materials
- Investigate super hard coatings for polycarbonate
- Investigate molded plastics as a substitute for aluminum component parts
- Investigate substitutes for butyl barrier films
- Finalize and validate specifications for material database selection and monitoring
- Continue to establish a database on new technologies

Optics

- Initiate design studies using a flat optic approach and FOV enhancement systems such as fresnel lenses
- Conduct a feasibility study on the use of low cost displays
- Continue to investigate the integration of laser, ballistics, and flash protection into designs
- Continue to establish a database on new technologies

Power Sources

- Perform calculations for estimated power consumption under various applications
- Continue to monitor developments in high density batteries
- Initiate design efforts to develop high efficiency motors tailored to system design features
- Continue to establish a database on new technologies

Seal Design

- Initiate study to isolate seal from facepiece

- Initiate study to optimize the use of positive pressure for seal design

Valves/Air Management

- Initiate design studies on automatic valving
- Conduct positive pressure air management studies
- Establish physiological limits for respiration
- Continue to establish database on new technologies

CRDEC presented three respirator concepts at the 1989 design workshop. The designs spanned the gamut from soft skin, form-fitting to semi-rigid, to hard shell and modular. Furthermore, the design accessories varied from very simple, passive designs (i.e. simple voicemitters requiring no power) to more sophisticated active voice amplifiers. The workshop attendees critiqued these three designs. The design critique resulted in the following recommendations and conclusions regarding each of the respective technologies to be employed in RESPO 21:

Recommendations

- Development of the three concepts should continue to the prototype stage. However, prior to further development each of the concepts needs to be further defined.
- A preliminary trade-off analysis is essential, particularly because a 100 percent solution to the performance decrements imposed by IPE is impossible to obtain using existing technologies.
- The need exists for a comprehensive, multi-threat analysis as performance and protection capability become more critical.

The conference participants agreed that the aforementioned recommendations need to be completed prior to holding Design Workshop Two.

Conclusions

- Continued CRDEC/NRDEC development coordination is essential
- Evolutionary designs with new requirements are expected
    - Potential future requirements include:
        - Increased Chemical/Biological protection
        - Increased Physiological requirements
        - Multiple threat protection

- Early trade-off determinations must be supplied for user evaluation

- Old ideas should be revisited with new design technologies. Highly desirable designs can be derived from incremental improvements to components and through the use of increased modularity

- Full face ballistics protection is a design driver

- Designs must interface with the SIPE headgear

- Lenses must be close to the eye to assure compatibility

- Reduced threat filters are not desirable

- Improved communication is essential

10.0 APPENDICES

10.1 Appendix A

Individual Protective Equipment Design Workshop Attendees List October 11-13, 1989

Dr. Robert S. Beaudet
University of Southern California
Department of Chemistry
Los Angelos, CA 90089-0482
(818) 795-4537

Ms. Carolyn Bensel
US Army NRDEC
ATTN: STRNC-YBF
Natick, MA 01760-5020
(508) 651-4780
AV 256-4780

Mr. Donald Benton
US Army CRDEC
ATTN: SMCCR-PPC
APG, MD 21010-5423
(301) 671-5779
AV 584-5779

Mr. John Boardway
1209 Vermont Road
Bel Air, MD 21014
(301) 838-5577

Mr. Morton S. Brisker
Battelle Edgewood Operations
2113 Emmorton Park Road
Suite 200
Edgewood, MD 21040
(301) 676-0200

Ms. Nancy R. Brletich
Battelle Edgewood Operations - CBIAC
2113 Emmorton Park Road
Suite 200
Edgewood, MD 21040
(301) 676-9030

Mr. Richard W. Brletich
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-5912
AV 584-5912

Ms. Stephanie Clewer
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-4204
AV 584-4204

Mr. Charles R. Crawford
US Army CRDEC
ATTN: SMCCR-ST
APG, MD 21010-5423
(301) 671-3570
AV 584-3570

Mr. Lynn Davis
US Army CRDEC
ATTN: SMCCR-ST
APG, MD 21010-5423
(301) 671-3933
AV 584-3933

Mr. Elmer H. Engquist
Battelle Edgewood Operations
2113 Emmorton Park Road
Suite 200
Edgewood, MD 21040
(301) 676-0200

Ms. Carol J. Fitzgerald
US Army NRDEC
ATTN: STRNC-TTE
Natick, MA 01760
(508) 651-5436
AV 256-5436

Mr. Harry Froehlich
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-2519
AV 584-2519

Dr. Ralph F. Goldman
Comfort Technology
P.O. Box 847
Framingham, MA 01701
(508) 651-1030

Dr. Gary W. Good
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201-2693
(614) 424-3924

Mr. Wesley Goodwin
US Army NRDEC
ATTN: STRNC-IC
Natick, MA 01760
(508) 651-4704
AV 256-4704

Mr. Corey M. Grove
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-5674
AV 584-5674

Captain Ricky Hamilton
Commander ASOCS
ATTN: ATSL-CD-CS
APG, MD 21010-5423
(301) 278-3456
AV 298-3456

Mr. David M. Harrah
US Army HEL
ATTN: SLCHE-CC
APG, MD 21005
(301) 278-5926
AV 298-5926

Mr. Francis P. Hughes
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-5915
AV 584-5915

Dr. Arthur T. Johnson
The University of Maryland
College of Agriculture
Dept. of Agric. Eng.
College Park, MD 20742
(301) 454-3901

Dr. Thomas Kulle
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-2313
AV 584-2313

Mr. John Maruscak
NADC
Code 60244
Warminster, PA 18974

Mr. Walter Meinhausen
USAARMS
ATTN: ATSB-CD-ML
Fort Knox, KY 40121
(502) 624-1750
AV 464-1750/8132

Ms. Cecilia Owens
Government Accounting
Office
441 G Street, Northwest
Washington, D.C. 20548
(202) 275-8333

Mr. Ernest S. Owens
Battelle Edgewood
Operations
2113 Emmorton Park Road
Suite 200
Edgewood, MD 21040
(301) 676-0200

Mr. Peter Paicopolis
US Army HEL
ATTN:SLCHE-CC
APG, MD 21005
(301) 278-5925
AV 298-5925

Major Charles R. Pavlick
U.S. Army Infantry School
ATTN: ATSH-CD-MLS
Fort Benning, GA 31905
(404) 545-3087
AV 835-3087

Mr. William Prusaczyk
USARIEM
ATTN: SGRUD-UE-MEP
Natick, MA 01760
(508) 651-5142
AV 256-5142

Mr. John A. Scavnicky
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-2448
AV 584-2448

Mr. George Schultheiss
US Army NRDEC
ATTN: STRNC
Natick, MA 01760
(508) 651-5444
AV 256-5444

Captain June Sellers
U.S. Army Chemical School
ATTN: ATZN-CM-CS
Fort McClellan, AL 36205
(205) 848-3877
AV 865-3877

Dr. Frank Shanty
5500 Knell Avenue
Baltimore, MD 21206
(301) 488-0172

Mr. Stan Sinclair
Newport Army Amaco
ATTN: SMCNE-(Contractor)
(317) 248-6465

Mr. Albert N. Tardiff
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-5798
AV 584-5798

Dr. Ronald A. Weiss
US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-2313
AV 584-2313

Mr. Joseph H. Zarzycki
US Army CRDEC
ATTN: SMCCR-PP
APG, MD 21010-5423
(301) 671-5600
AV 584-5600

10.2 Appendix B

Predictive Model Types

Written By Dr. Ralph F. Goldman

There are many different types of predictive models. These can be generally categorized as follows:

- o Theoretical Models
- o Single Study Data Fitted Models
- o Data Base derived models
- o Validated, data base derived models

While this system of classification may not be all-inclusive, it appears to incorporate most of the applicable models concerned with thermal stress prediction and resultant human performance and seems an appropriate point of departure for respiratory effects models.

1. Theoretical Models

Theoretical models are those based on a framework derived from hypothetical considerations, with little or no data used in the derivation of the model. One example would be the postulated relationship between need, expectancy and motivation widely used in the 1960's to consider the differences in performance between groups of varying backgrounds. Other examples include the dual models of electromagnetic energy in the form of waves or as quanta of energy. In other words, theoretical models are derived by attempting to match a very limited number of data points with a theory which suggests how the relationships might function. Some have become well accepted and are widely used, for example the Dirac model of matter and anti-matter. They have a possible advantage in not having tremendous face validity (looks valid), and perhaps the disadvantage of being able to predict only to a very limited degree.

2. Single Study Data Fitted

Single study data fitted models are perhaps the most widely available. They are derived by simply attempting to develop a mathematical equation, or set of equations, which provides a best fit regression for study data from which they are derived. These models are of extremely limited utility for further prediction. Their primary advantage is to help provide an understanding of the relationships observed within the given study. Whether they can validly be used to predict the results of subsequent studies is questionable, although sometimes attempted. Their utility as a true prediction model is very limited. Examples of this type of modeling include that of Hayward for cold immersion, and Snook for acceptable industrial weight lifts. Fanger's model for prediction of thermal comfort is included in this category although his model is a mix of theoretical considerations and the

reported comfort votes of well over three thousand subjects collected over a number of years. Nevertheless, the standard error of estimates of his model, plus or minus one full-scale unit, indicates the imprecision and low predictive yield of his model.

3. <u>Data Base Derived</u>

Data base derived models are developed by fitting equations, not just to the data from a single study or single type of study repeated a number of times, but to a broad range of studies conducted by a variety of investigators under various conditions. The work of Wyon and his group on performance prediction under mild thermal stress and the analysis of performance across a broad spectrum of physiological tasks by Wing, using effective temperature as a common denominator for thermal stress, are examples of this type of modeling. Such models are extremely useful in summarizing what is known about a given subject. Their greatest weakness is that their use in predicting performance under conditions of a subsequent performance test should be considered suggestive, but may not be at all reliable.

4. <u>Validated Data Base Derived</u>

The fourth classification of model type is similar to the third class except for the requirement of validation. This requirement for validation consists of using the model as developed against one "body of knowledge", running predictions to select an adequate set of test conditions to differentiate between responses (i.e. using the model to select conditions where measurable differences are anticipated), and then exercising the model to determine whether or not the observed results in the subsequent test validate the predictions made by the model. If only minor refinements in coefficients are required to produce reasonable agreement between the observed and predicted results, the model can be considered valid within certain confidence limits. Additional validation studies, involving extrapolation beyond the range of data upon which the model was originally derived, are particularly useful in determining the range of validity of the model. Obviously, if the range of experimental conditions changes the emphasis of human response from one physiological or psychological regulatory domain to another, one should not expect validity to be maintained. In much the same way, the mean value theorem used in theoretical analysis does not expect validity to be maintained. In much the same way, the mean value theorem used in theoretical analysis does not hold across a finite discontinuity. Thus, models developed for heat stress should not be expected to work well for cold conditions, although they may be good enough for limited use under certain comfortable conditions.

Developing such validated models is not a short-term proposition. Rather, such models develop slowly, over a period

of years with small subelements added to improve or extend the model. Coefficients may be modified, or added, to deal with additional factors, tests must be run to validate the modified coefficients and new factors should be added to the model to assure that the original predictive validity is still maintained or improved by the latest refinements. Few groups have the luxury of continued support for such a sustained, multi-year, multi-faceted program. Therefore, it is not surprising to find that such modeling has usually been carried out under Government sponsorship and, even then, by very few laboratories. The USAF School of Aerospace Medicine (USAFSAM); USA Research Institute of Environmental Medicine (USARIEM); Loten's group in the Netherlands; Wyndham's group in South Africa dealing with heat acclimatization and the hot/wet conditions found in the deep mines; Wyon's group in Scandinavia; and Fanger's group working on comfort at the Danish Technical Institute over the last several decades, are examples of continuing program emphasis on modeling, parameter addition and revalidation efforts. The requirement for access to substantial human test subject population and significant resources and facilities for studying their responses make the support for such efforts difficult to obtain, and, therefore, limit the number of organizations who conduct such studies and modeling efforts.

What are the requirements for a valid heat stress model? Such a model must be able to assess the heat production of the task performer, since this is a major element and can result in heat stress occurring at temperatures even below freezing when heavy clothing is worn. Such a model must be able to handle varying levels of clothing. Many models are limited to addressing only a single level of clothing (i.e. T-shirt and shorts or standard long-sleeve shirt and trousers.) Finally, models able to handle significant heat stress, rather than those dealing with minor heat discomfort, must be able to handle the sweat evaporative cooling allowed by the clothing. From all information that was obtainable, only the Givoni-Goldman models developed at the US Army Research Institute of Environmental Medicine have this capability. It would appear that these models should be used to predict the performance of the USAF ground crews when wearing chemical defense ensembles with varying degrees of permeability. However, a possible alternative is to accept the fact that the microclimate within such clothing ensembles is almost always a saturated, 100 percent relative humidity (RH) environment at a close to skin temperature 33 degrees to 36 degrees Centigrade (91.4 - 96.8 degrees Fahrenheit). With such an assumption, one can use the rather extensive data base that Wyndham has developed on workers in the deep mines in South Africa where similarly high ambient temperatures at 100 percent humidities have been encountered. Otherwise, the only acceptable data base for modeling should be a compilation of the empirical findings obtained by studying performance in chemical protective clothing. Custance has summarized the results of six such studies from Canada, the United States, the Soviet Union, etc., and presented a table

which is quite consistent with the general experience in terms of tolerance time limits for the performance of moderate work. Such an approach, however, has difficulty with more subtle performance alterations than the gross tolerance time for work (i.e. determining performance under less than tolerance limiting conditions is difficult to estimate using this approach). An example of such modeling is given in the description of the "MIPPS" model of Comfort Technology for a "Military Performance Prediction System".

5. Identification of Data Gaps

Investigation to identify the appropriate physiological variables that can be related to performance revealed the existence of many data gaps. For example, a method of representing physical conditioning, skill level or acclimatization using a numerical representation proved very difficult. For this reason, as well as the fact that thermal burden affects the indicators of performance in more ways than one, a simple curve of core temperature over time was not feasible; a much higher level of difficulty is involved in preparing and presenting the information in a statistically valid and usable format. A curve of core temperature versus time would have to be drawn for a number of conditions held constant (i.e. environmental, task, and individual characteristics).

Although physiologists have provided excellent data pertaining to the interaction between clothing and the body, this information is very specialized in terms of experimental conditions and usually is not transferable among studies. The psychologists have made an effort to provide an understanding of performance in protective clothing but physiological indicators were not always used in conjunction with performance measures. Therefore, a significant data gap involves the lack of studies conducted jointly by a team of psychologists, physiologists, and statisticians to ensure that appropriate experimental studies are conducted.

6. Categories of Performance Decrement

In light of the inability to provide specific curves of physiological indicators, such as core temperature, versus performance to establish categories of performance decrement, certain trends from review of the literature and the information provided in forty four relevant studies have been examined.

For cognitive, motor and dexterity tasks, the following core temperatures can be stated as the "average" for certain levels of performance degradation:

COGNITIVE:

CORE TEMPERATURE	DEGRADATION

39.6 degrees C/104.4 degrees F	Complete
38.5 degrees C/101.3 degrees F	Extreme
38.3 degrees C/100.9 degrees F	Moderate
37.7 degrees C/99.9 degrees F	Slight
37.2 degrees C/98.96 degrees F	None

MOTOR:

CORE TEMPERATURE	DEGRADATION
40.2 degrees C/104.4 degrees F	Complete
38.9 degrees C/102.0 degrees F	Extreme
38.5 degrees C/101.3 degrees F	Moderate
38.1 degrees C/100.6 degrees F	Slight
37.2 degrees C/98.96 degrees F	None

DEXTERITY:

CORE TEMPERATURE	DEGRADATION
39.0 degrees C/102.2 degrees F	Complete
38.8 degrees C/ 101.8 degrees F	Extreme
38.0 degrees C/100.4 degrees F	Moderate
37.72 degrees C/99.9 degrees F	Slight
37.2 degrees C/98.96 degrees F	None

NOTE: These core temperatures are means. There is no doubt, based on individual differences, that not every individual will have the same response to each of these temperatures. Generally, performance on tasks can be expected to diminish as each of these temperatures are reached.

Based on these categories of degradation, ranges of percent decrement are assigned to each of these five points for each task type. It can be stated that at normal core temperatures, degradation will be from 0 to 20 percent, which is to be expected based upon industrial work productivity studies. If 80 percent to 100 percent degradation is assigned to the highest core temperature and the remaining 60 percent are distributed evenly to the other three levels of core temperature (2 0%-40%, 40%-60%, 60%-80%), then ranges of decrement could be theoretically stated.

The data gap in making such analysis and predictive categories lies in determining what each range of performance decrement actually means. The question remains whether this degradation is defined as increased time to perform a task, as the number of errors increases, or the error rate increases. For example, if an individual must dispose of a bomb (EOD dexterity task) and it takes thirty minutes, but the ambient conditions cause a rise in core temperature to 37.7 degrees C (99.9 degrees

F) after 20 minutes of work, performance may be degraded by 20 to 40 percent. But it is unknown what performance problems will be exhibited in this level of decrement. In this case, will it be errors in omission, accuracy, increased time to perform, or hand tremors?

It must be noted that the emphasis on core temperature in many studies has been for reasons of safety rather than as a metric against which to depict performance. Use of core temperature alone is only a first approximation for mission performance short of tolerance time limitations, and a particularly poor one where wear of CDE is involved. One should prepare performance data against a data base of core temperatures obtained at rest, as well as at work, further confounded by wear of minimal, conventional, or CDE and by varying thermal or metabolic drives to core temperature if there are no indicators available. The following table, prepared by Dr. Goldman, suggests a method for selecting a set of key indicators and stressors associated with mission performance problems and development of modeling concepts.

Key Indicators and Stressors
Associated with Wear of CDE (Predictive Modeling Goals)

I. Psychological Indicators: Stress Imposed by CDE

Audition:	Impaired oral communication (Command/Control)
Vision:	Impaired target acquisition/identification
Dexterity:	Impaired manual dexterity (Gloves/sweat)
Mental Processing:	Impaired judgement from decreased blood flow to the brain
Attention/ Vigilance:	Focus on central task to the detriment of secondary tasks
Discomfort/ Distraction:	Severe discomfort or pre-physiological problems leading to "I quit" decision
Effort Sensation:	Work effort perceived as too hard or demand of task greater than the human capacity

II. Physiological Stress

Physical Exhaustion:	Inadequate circulation of oxygen to working muscles leading to intracellular changes in cell acidity and disruption of normal cellular function. Frequently associated with the narrowing of the core to skin temperature gradient resulting from limited sweat evaporation.

Dehydration Exhaustion:	Physical exhaustion enhanced by reduced circulating blood volume. Frequently associated with limited water intake.
Heat Exhaustion:	Inadequate circulation of oxygen to the brain
Sweat Exhaustion:	Sustained skin wettedness is associated with sweat suppression and sweat gland plugging (documented by Pandolf, Griffen and Goldman to reduce heat tolerance)
Stress:	Possible, but not well documented for CDE, with most studies being limited to hours rather than days; depletion of the body's energy reserves (Glycogen stores and emotional stores) as a result of excess mental and physical stress

These five physiological states of exhaustion (stressors) delineated above are not independent of one another; rather they are interactive and associated with the following physiological indicators:

Hyperventilation: Overbreathing, analogous to panting in dogs to increase heat loss from the tongue; in man, the resulting drop in the level of carbon dioxide in the blood can result in constriction of blood vessels in the brain, lowered mental function, reduced vision, and in severe cases, blackout. Great variability in individual susceptibility (related to "respiratory drive"), and more prevalent under hot, humid conditions.

Skin Temperature Converging Toward Core Temperature: Results in increased competition for cardiac output for:

- o Delivery of oxygen to the brain and working muscle stated as:

  $\dot{V}O_2$ = (Stroke Volume) X (Heart Rate) X (Arterial-Venous Oxygen Difference); where VO_2 is the capacity of the circulating blood to deliver oxygen to the working muscles and stroke volume is the amount of blood released by the heart in one contraction.

- o Removal of heat from body core to skin surface for subsequent elimination, if allowed by sweat production, clothing limitations on sweat evaporation (I_m/CLO) and/or ambient vapor pressure, stated as:

  Core to skin heat flow = Stroke Volume X Heart Rate X (Core - Skin Temperature)

High Heart Rate: With maximum heart rate predictable as 220 beats per minute minus age in years, and heart rate as driven upward by convergence, tolerance time becomes limited. Note that

stroke volume reaches its maximum at about 15 to 20 percent of maximum oxygen uptake so the only capacity the body can draw upon to meet the increased demand for oxygen delivery/heat removal is to increase heart rate.

Increasing Core Temperature: Driven independently by work rate (36.7 degrees C + 0.04 X Metabolic Rate in Watts), high core temperature (T_{re}) per se is not limiting unless it reaches levels where nerve cells are damaged (heat stroke - temperature regulating nerve centers in the brain show signs of damage at T_{re} > 41 degrees C (105.8 degrees F) and damage is often fatal at T_{re} > 42 degrees C (107.6 degrees F). Usually increasing T_{re}, by enlarging the core-shell temperature gradient, reduces the circulatory demands for elimination of body heat. However, increasing core temperature above that expected for a given workload is evidence of body heat storage as a result of inadequate heat loss. It is usually accompanied by core-skin temperature convergence unless an equilibrium state of body heat balance can be established with a core skin to ambient temperature gradient (and skin to ambient vapor pressure gradient) sufficient to allow adequate heat loss despite the insulation (CLO) and moisture permeability index ratio (I_m/CLO) of the CDE resistance, modified by the pumping coefficient of wind and body motion.

Increased Sweat: Sweat production rate provides an integrated analysis of the overall difficulty the body is experiencing with a given mission. Driven both by the demands for heat loss and by the limitations on sweat evaporation imposed by protective clothing and the microclimate within an ambient environment, ability to predict the actual sweat rate provides a linked, but in another sense independent assessment of mission performance capability. Other parameters will need to be invoked for modeling respirator/hood effects. However, a number of the elements already embedded in "MIPPS" can be used to build upon.

10.3 Appendix C

IPE Technology Workshop Review

Presented By Mr. Corey M. Grove

US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671- 5674
AV 584-5674

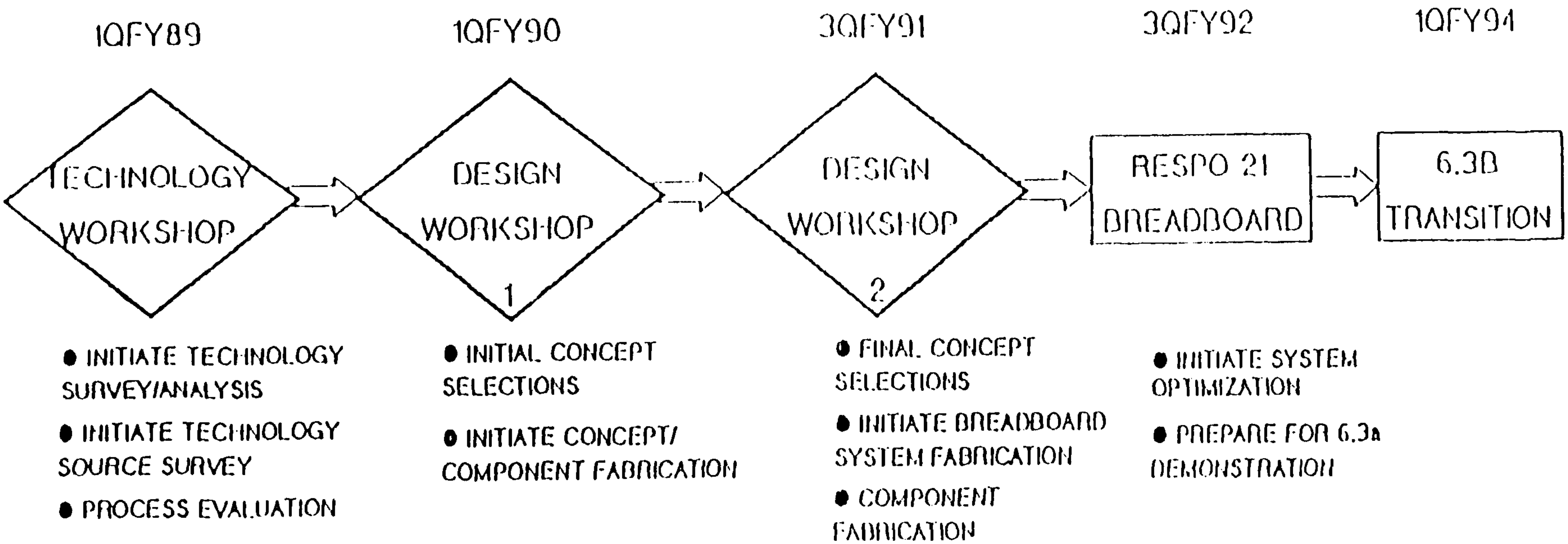
CRDEC/NRDEC

INDIVIDUAL PROTECTION EQUIPMENT

DESIGN WORKSHOP #1

INDIVIDUAL PROTECTION

RESPO 21 DESIGN PROGRAM



RESPO 21

DESIGN WORKSHOP #1

WORKSHOP GOALS

- ESTABLISH INITIAL RESPO 21 DESIGN CONCEPTS
- DEFINE OPERATIONAL FEATURES OF SELECTED CONCEPTS
- ASSOCIATE CONCEPTS WITH FUTURE OPERATIONAL NEEDS

RESPO 21 PROGRAM
(PROGRAM EMPHASIS)

FOCUS (FRONT END ANALYSIS)

- MAINTAIN PROTECTION
- IMPROVE INTEGRATION
- MINIMUM MISSION DEGRADATION

PRIMARY DESIGN CATEGORIES

- MISSION DEGRADATION
- CB PROTECTION
- LOGISTICS/RELIABILITY
- SYSTEM INTEGRATION

PREVIOUS FOCUS

FEA FOCUS

- MULTIPLE THREAT (NRDEC)

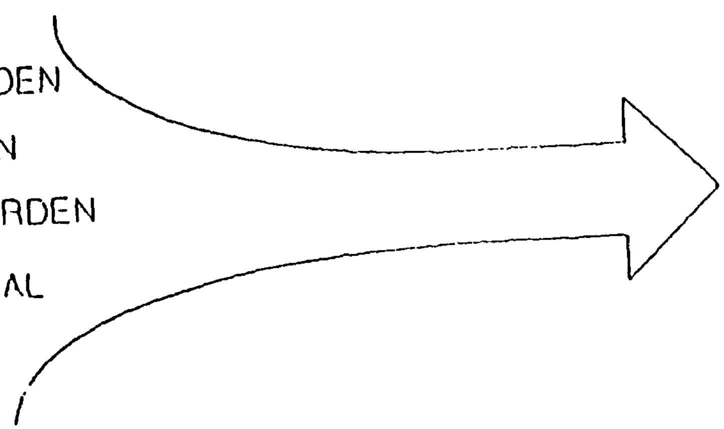
NOTE: FRONT END ANALYSIS RESULTS DID NOT EXPLICITLY EXPRESS MULTIPLE THREAT PROTECTION AS IS BEING ADDRESSED BY NRDEC.

RESPO 21 PROGRAM

(NEW FOCUS DEFINITIONS)

MISSION DEGRADATION

- O THERMAL BURDEN
- O RESPIRATORY BURDEN
- O METABOLIC BURDEN
- O HUMAN FACTOR BURDEN
  - \- BIOMECHANICAL
  - \- SENSORY
- O PSYCHOLOGICAL



100% TOTAL DEGRADATION

NOTE: ONLY THERMAL BURDEN RELATIVELY WELL DEFINED. BOTH INDIVIDUAL PARAMETER DEFINITION AND INTERACTIONS NEED DEFINITION THROUGH INTEGRATED MODELING.

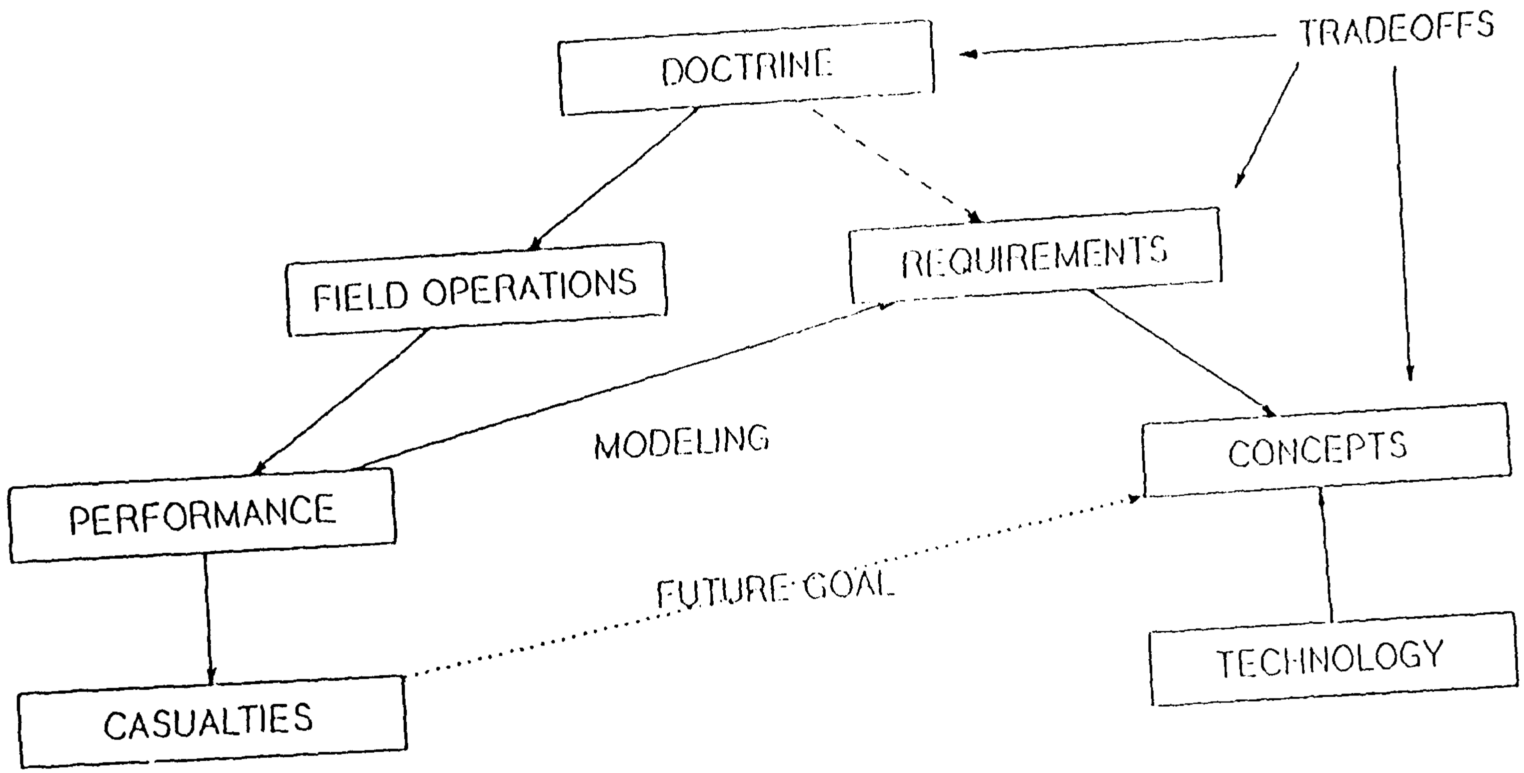
RESPO 21 PROGRAM

(MISSION DEGRADATION)

PHYSIOLOGICAL			HUMAN FACTOR		
THERMAL	RESPIRATORY	METABOLIC	BIOMECHANICAL	SENSORY	PSYCHOLOGICAL
SKIN TEMP. CORE TEMP. HEAT REMOVAL - RATES - GRADIENTS	RESISTANCES FLOW RATES AIR TEMP. O2 CONTENT CO2 CONTENT DEAD SPACE VOL.	DRINKING FEEDING WASTE REMOVAL	DEXTERITY SYSTEM WEIGHT SYSTEM BULK DISCOMFORT INTEGRATION	EYE STRAIN FIELD-OF-VIEW ACOUSTICAL - TRANSMISSION - HEARING	CLAUSTROPHOBIA DISTRACTION CONSUMABLES DISCOMFORT
%	%	%	%	%	%
TOTAL DEGRADATION = 100%					

NOTE: EACH VARIABLE MUST BE SEPARATED FROM THE OTHERS DURING TESTING TO UNDERSTAND AND MODEL THE TOTAL DEGRADATION. EACH WILL ALSO VARY ACCORDING TO THE FIELD OPERATION (TASK, ENVIRONMENT, AND DURATION).

RESPO 21 PROGRAM
(DESIRED APPROACH)



NOTE: USER IS AWARE OF TECHNOLOGY BARRIERS AND WORKS TRADEOFFS WITH DEVELOPER. MODELING IS INTEGRATED FOR PERFORMANCE ESTIMATES.

TECHNOLOGY WORKSHOP RESULTS

(PROGRAM DIRECTION)

- USER REQUIREMENTS NEED <u>DEFINITION</u> AND <u>PRIORITIZATION</u>
- MODELING ESSENTIAL FOR <u>ADEQUATE</u> DEFINITION OF MISSION DEGRADATION
- MODEL INPUT PARAMETERS NEED DEFINITION THROUGH TESTING
- MODEL INTEGRATION IS KEY TO TOTAL DEFINITION OF MISSION DEGRADATION
- CAD/CAM/CAE PROVIDES USEFUL CAPABILITIES
- TOTAL SYSTEM TESTING AND FIELD REPLICATION REQUIRE PARALLEL DEVELOPMENT
- THREAT/OPERATIONAL DATA NEEDED FOR ADEQUATE CONCEPT DEFINITION
- IMPROVED DEVELOPER COORDINATION IS NEEDED FOR TOTAL SYSTEM DEVELOPMENT

TECHNOLOGY WORKSHOP RESULTS

(6.2 TECHNOLOGY AREAS)

- AGENT PROCESSING
  - CHARCOAL/FIBER
    - SORBENT MIXTURES/SUPERADSORBENTS
    - BONDED CARBON
  - PLASMA DISCHARGE/ELECTROSTATICS
  - DETOXIFYING FILTRATION MEDIA
  - TOTAL ENCAPSULATION
  - ADAPTATION/RECOGNITION
- THERMAL BURDEN CONTROL
  - BLOWN AIR/LIQUID COOLING/PHASE CHANGE
  - VENTING/MOPP REVISIT
  - HEAT ABSORBING MATERIALS
  - LAYERS/MULTIPURPOSE LAMINATES
  - WETTING/SWEAT REMOVAL
  - MICROCLIMATIC COOLING
  - ADAPTATION/RECOGNITION
  - IMPROVED TRAINING
- RESPIRATORY BURDEN CONTROL
  - SMART VALVING
  - CO2 SCRUBBERS
  - INCREASED SURFACE AREA
  - FORCED AIR
  - ADAPTATION/RECOGNITION
  - IMPROVED TRAINING
- COMMUNICATIONS
  - AMPLIFIED RECEIVERS/TRANSMITTERS
  - NETWORK COMMUNICATIONS
- OPTICS
  - CLOSE FITTING LENSES/AIR MANAGEMENT SYSTEM
  - FRESNEL LENSES
  - HALOGRAPHICS
  - HMD/FLIR TECHNOLOGY
- PSYCHOLOGICAL/BIOMECHANICAL
  - OPEN/CLEAR FACEPIÉCES
  - NOSECUP SUBSTITUTES
  - INDICATORS
  - IMPROVED TRAINING
- POWER SOURCES
  - HIGH DENSITY BATTERIES
  - SOLAR CELLS
  - GALVANIZING
  - BIOMECHANICAL GENERATORS
- MATERIALS
  - COPOLYMERS/COMPOSITES
  - FLEXIBLE/RIGID OPTICAL MATERIALS
  - RESIDUAL LIFE INDICATORS

TECHNOLOGY WORKSHOP RESULTS

(6.1 RESEARCH AREAS)

- TRANSPORT MECHANISMS IN MATERIALS
- PHYSIOLOGICAL EFFECTS
  - INHALATION/EXHALATION EFFECTS
  - INTERACTION OF CO_2
  - RESISTANCE/PERFORMANCE TESTS
  - PSYCHOLOGICAL EFFECTS
- MATERIALS
  - CONFORMABLE
  - ONE-WAY VAPOR TRANSPORT
  - OPTICALLY CLEAR
  - BONDED CARBON
  - THERMAL RELEASE
  - CO_2 TRANSPORT
  - ELECTRICALLY CONDUCTING POLYMERS
- CHEMISTRY OF AGENTS
- CHEMICAL MICROSENSORS
- POWER SOURCES
  - MINITURIZATION
  - BIOMECHANICAL GENERATORS
- MODEL DEFINITION/INTEGRATION
- TEST METHODOLOGY/TECHNIQUES

TECHNOLOGY WORKSHOP RESULTS

(COMPLEX ISSUES)

- OPERATIONAL/THREAT/TRAINING CONDITIONS SHOULD BE REVIEWED FOR BALANCED SOLUTION TO MISSION DEGRADATION PROBLEM
- INTEGRATED MODELING IS NEEDED TO ADEQUATELY DEFINE MISSION DEGRADATION
- ADDITIONAL PARAMETER DEFINITION IS NEEDED TO UNDERSTAND THE INDIVIDUAL COMPONENTS OF MISSION DEGRADATION AND THEIR INFLUENCES ON EACH OTHER
- HEAD COOLING CANNOT SOLVE THERMAL BURDEN PROBLEM ALONE
- ADDITIONAL DATA IS NEEDED TO ADEQUATELY DEFINE CONCEPTS
- ADAPTABILITY MAY BEST SOLVE FUTURE DEVELOPMENT GOALS

RESPO 21 PROGRAM

(PROGRAM BARRIERS)

TECHNOLOGY BARRIERS

- POWER SOURCES

  - CURRENT PROJECTIONS INDICATE BATTERY IMPROVEMENTS ARE REACHING THEORETICAL MAXIMUMS

  - OTHER SOURCES EITHER PRESENT UNREALISTIC SAFETY/LOGISTIC PROBLEMS OR DO NOT PROVIDE ADEQUATE POWER DENSITY.

  APPROACH – PROVIDE HYBRID POWER AND OPTIMIZE POWER REQUIREMENTS.

- MATERIALS

  - MATERIALS DO NOT EXIST TO MEET MANY OF THE CURRENT DEMANDS.

  APPROACH – FOCUS ON HYBRID MATERIALS (ie. BLENDS) AND OPTIMIZE.

- SIGHTING SYSTEM INTEGRATION

  - INTEGRATION MAY BE KEY TO FUTURE COMPATIBILITY PROBLEMS

  APPROACH – INITIATE STUDIES ON INTEGRATION

- MICROPROCESSOR SENSORS AND CONTROL SYSTEMS

  - AUTOMATIC CONTROL SYSTEMS MAY BE KEY TO FUTURE ADAPTABILITY

  APPROACH – INITIATE STUDIES ON FEASIBILITY

RESPO 21 PROGRAM

(PROGRAM BARRIERS)

OTHER BARRIERS

- PROGRAM APPROACH

  – A NOVEL DEVELOPMENT APPROACH MAY BE NEEDED TO FULLY ADDRESS THE REMAINING USER CONCERNS.

- MULTIPLE THREAT

  – A PROGRAM DECISION IS NEEDED TO DETERMINE THE LEVEL OF ATTACK REGARDING MULTIPLE THREAT DEVELOPMENT.

- INTEGRATED MODELING

  – DATA IS NOT CURRENTLY AVAILABLE TO ALLOW DEVELOPMENT OF INTEGRATED MODELS WITHIN CURRENT PROGRAM TIMEFRAMES.

- ADAPTABILITY

  – TECHNOLOGIES NEEDED FOR CREATING THE ULTIMATE ADAPTABLE SYSTEM ARE NOT AVAILABLE WITHIN CURRENT PROGRAM TIMEFRAMES.

TECHNOLOGY WORKSHOP RESULTS

(CURRENT ASSESSMENT)

MODULAR → ADAPTABLE → ENHANCEMENT

MODULAR

DESIGN

- SYSTEM INTERFACE COMPATIBILITY
- R INTEGRATION AS APPROPRIATE
- ENSEMBLE INTERFACE INTEGRATION
- HYBRID COOLING
- SUPERADSORPTION/SORBENT MIXTURES UTILIZING IMMOBILIZED BED TECHNOLOGY
- CLEAR/OPEN FACE AND INSIGNIA RECOGNITION
- BEHAVIORAL ADAPTABILITY/MODULARITY
- ELIMINATE HOOD PRESSURIZATION FOR UNBLOWN OPERATION
- FORCED AIR MODULARITY
- UTILIZE CONFORMABLE; OPTICALLY CLEAR, BONDED CARBON MATERIALS

BASELINE

- SYSTEMATICALLY IDENTIFY CRITICAL PERFORMANCE MEASUREMENTS(THERMAL, RESPIRATORY,PSYCHOLOGICAL,HUMAN FACTORS) AND APPLY ANALYSIS/MODELING TECHNIQUES FOR INDEPENDENT DESIGN APPLICATION
- OPERATIONAL/THREAT/TRAINING REVIEW TO MINIMIZE REMAINING BURDENS
- INDEPENDENT DATABASE/CAE APPLIC.

ADAPTABLE

DESIGN

- TOTAL DEFENSE SYSTEM INTEGRATION
- TOTAL ENCAPSULATION
- MICROCLIMATIC COOLING
- PLASMA DISCHARGE/IONIZATION ENHANCED
- NETWORKED COMMUNICATIONS/RECOGNITION
- AUTOMATIC ADAPTATION TO ENVIRONMENT
- IMPROVED BALLISTICS PROTECTION
- UTILIZE THERMAL RELEASE, VAPOR/CO2 TRANSPORT,CONDUCTING POLYMER MATERIALS
- AUTOMATIC (SMART) PROCESSORS
- HMD/FLIR SIGHTING SYSTEM INTEGRATION

BASELINE

- ALL PERFORMANCE MEASUREMENTS/MODELS (THERMAL,RESPIRATORY, HUMAN FACTORS, AND PSYCHOLOGICAL) WELL DEFINED AND INTEGRATED FOR WEIGHTED ANALYSIS
- OPERATIONAL/THREAT/TRAINING REVIEWED AND BALANCED TO OVERCOME REMAINING BURDENS
- TOTAL IR&D DATABASE INTEGRATION
- TOTAL CAE/MODEL INTEGRATION

ENHANCEMENT

DESIGN

- INDIVIDUAL SOLDIER ENHANCEMENT
- OFFENSE/DEFENSE POSTURE INTEGRATION
- WEAPON SYSTEM INTEGRATION

RESPO 21

DESIGN WORKSHOP #1

SPECIAL REQUIREMENTS

FITTING - 1-99% GOAL

TIME TO PROTECTION - 9 SEC.

SERVICE TIME UNDER CHALLENGE - 24 HOURS (72 DESIRED)

SERVICE TIME WITHOUT CHALLENGE - >120 DAYS

RELIABILITY - COMPARABLE TO M40 SERIES

SURVIVABILITY - AR70-71

OPERATIONAL TEMPERATURES: -25F - 120F

STORAGE - -60F - 160F

SERVICE LIFE - 10 YEARS

LOGISTICS - COMPARABLE TO M40 SERIES

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

SEAL DESIGN

RECOMMENDATION SUMMARY

- Initiate study to isolate seal from facepiece
- Initiate study to optimize the use of positive pressure for seal design

AVAILABLE TECHNOLOGIES

CONFORMABLE MATERIALS

SCAVENGING

PRESSURIZATION

ENCAPSULATION

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

AGENT PROCESSING

RECOMMENDATION SUMMARY

- Initiate advanced filter design studies to include:
  - Low profile, easy replacement attachments
  - Polymeric housing
  - Immobilized bed technology
  - ASZ-TEDA implementation
- Conduct feasibility study on electrically enhanced filtration
- Conduct feasibility study on prefilter humidity control systems
- Investigate reduced size specialty canister designs for improved performance adaptability
- Continue to establish database on new technologies

AVAILABLE TECHNOLOGIES

SORBENT MIXTURES

SUPERADSORBENTS

BONDED CARBON/IMMOBILIZED BED

PLASMA/CORONA DISCHARGE

ELECTROSTATICS

HUMIDITY CONTROL

DETOXIFYING FILTER MEDIA

CHEMICAL MICROSENSORS

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

COOLING SYSTEMS

RECOMMENDATION SUMMARY

- Investigate custom high efficiency blower design
- Monitor microclimatic cooling progress and allow for adaptation
- Investigate heat/moisture absorbing materials for hood/suspension design
- Continue to establish a database on new technologies

AVAILABLE TECHNOLOGIES

MICROCLIMATIC COOLING

LAYERS/MULTIPURPOSE LAMINATES

HEAT/MOISTURE ABSORBING MAT'LS

SILENT BLOWERS/PUMPS/ETC.

ENVIRONMENTAL MICROSENSORS

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

VALVES/AIR MANAGEMENT

RECOMMENDATION SUMMARY	AVAILABLE TECHNOLOGIES
- Initiate design studies on automatic valving	PRESSURIZATION
- Conduct positive pressure air management studies	AUTOMATIC VALVING
- Establish physiological limits for respiration	CO_2 ABSORPTION SYSTEM
- Continue to establish database on new technologies	PRESSURE MICROSENSORS.

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

COMMUNICATIONS

RECOMMENDATION SUMMARY

- Continue assessment of amplified voicemitters
- Investigate hybrid (no power) voicemitter designs
- Revise communication standards to align with field problems (ie. CANE Studies)
- Continue to establish database on new technologies

AVAILABLE TECHNOLOGIES

AMPLIFIED RECEIVERS/TRANSMITTERS

NETWORK COMMUNICATIONS

IR COMMUNICATIONS

DETECTOR INTERFACE.

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

OPTICS

RECOMMENDATION SUMMARY

- Initiate design studies using a flat optic approach and FOV enhancement systems such as fresnel lenes

- Conduct a feasibility study on the use of low cost displays

- Continue to investigate the integration of laser, ballistics, and flash protection into designs

- Continue to establish a database on new technologies

AVAILABLE TECHNOLOGIES

FRESNEL LENSES

HOLOGRAPHICS

MULTIPURPOSE COATINGS

VISUAL DISPLAYS

STACKED FILTERS

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

POWER SOURCES

RECOMMENDATION SUMMARY

- Perform calculations for estimated power consumption under various applications
- Continue to monitor developments in high density batteries
- Initiate design efforts to develop high efficiency motors tailored to system design features
- Continue to establish a database on new technologies

AVAILABLE TECHNOLOGIES

SOLID POLYMER CELLS

SOLID OXIDE FUEL CELLS

NATURAL ELECTROLYTE CELLS

SOLAR ARRAYSAYS

NUCLEAR CELLSRS

SUPERCONDUCTIVITY

RESPO 21

(TECHNOLOGY REVIEW RESULTS)

MATERIALS

RECOMMENDATION SUMMARY	AVAILABLE TECHNOLOGIES
- Investigate strip coatings for silicone	COPOLYMERS/COMPOSITES/ALLOYS
- Investigate silicone copolymers as flexible optical materials	CONFORMABLE MATERIALSS
	LIQUID CRYSTAL POLYMERSLS
- Investigate super hardcoatings for polycarbonate	SEMIPERMEABLE MEMBRANES
- Investigate molded plastics as a substitute for aluminum component parts	HEAT ABSORBING MATERIALS
	LT CATALYTIC MATERIALS
- Investigate substitutes for butyl barrier films	REACTIVE FILMS/FIBERS
- Finalize and validate specifications for material database selection and monitoring	PIEZOPOLYMERS
	BIOTECHNOLOGY
- Continue to establish a database on new technologies	

RESPO 21 TECHNOLOGY AREAS

(OTHER PRIMARY DESIGN ELEMENTS)

KEY
C= CRDEC IMPLEMENTATION
N= NRDEC IMPLEMENTAION
M= MONITORING
P= REQUIRES POWER

SEAL DESIGN

- C - CONFORMABLE MATERIALS
- C - SCAVENGING
- C - PRESSURIZATION
- NP - ENCAPSULATION

AGENT PROCESSING

- C - SORBENT MIXTURES/SUPERADSORBENTS
- C - BONDED CARBON/IMMOBILIZED BED
- MP - PLASMA/CORONA DISCHARGE
- CP - ELECTROSTATICS/HUMIDITY CONTROL
- M - DETOXIFYING FILTER MEDIA
- CP - CHEMICAL MICROSENSORS

POWER SOURCES

- MP - SOLID POLYMER CELLS
- MP - SOLID OXIDE FUEL CELLS
- MP - NATURAL ELECTROLYTE CELLS
- MP - LITHIUM INTERHALOGEN FUEL CELLS
- MP - SOLAR ARRAYS
- MP - NUCLEAR CELLS
- MP - SUPERCONDUCTIVITY

MATERIALS

- C - COPOLYMERS/COMPOSITES/ALLOYS
- C - CONFORMABLE MATERIALS
- C - LIQUID CRYSTAL POLYMERS
- M - SEMIPERMEABLE MEMBRANES
- C - HEAT ABSORBING/RELEASING MATERIALS
- M - LT CATALYTIC MATERIALS
- M - REACTIVE FILMS/FIBERS
- M - PIEZOPOLYMERS
- M - BIOTECHNOLOGY

MANUFACTURING

- C - CAD/CAM AND COMPUTER SIMULATION
- M - STEREOLITHOGRAPHY
- M - REACTIVE MOLDING
- M - RADIATION CURING

RESPO 21 TECHNOLOGY AREAS

(PRIMARY BURDEN CONTROL ELEMENTS)

KEY:
C= CRDEC IMPLEMENTATION
N= NRDEC IMPLEMENTATION
M= MONITORING
P= REQUIRES POWER

- **DESIGN** (BIOMECHANICAL/PSYCHOLOGICAL BURDEN CONTROL)

C - BEHAVIORAL ADAPTATION (UNPOWERED)
CP - AUTOMATIC ADAPTATION (POWERED)
NP - SYSTEM INTEGRATION
NP - BIOCYBERNETICS

- **COOLING SYSTEMS** (THERMAL BURDEN CONTROL)

NP - MICROCLIMATIC COOLING
C - LAYERS/MULTIPURPOSE LAMINATES
C - HEAT/MOISTURE ABSORBING MATERIALS
CP - SILENT BLOWERS/AIR PUMPS/COMPRESSORS
CP - ENVIRONMENTAL MICROSENSORS

- **OPTICS** (SENSORY BURDEN CONTROL)

C - FRESNEL LENSES
M - HOLOGRAPHICS
C - MULTIPURPOSE COATINGS
CP - VISUAL DISPLAYS
M - STACKED FILTERS

- **VALVES/AIR MANAGEMENT** (RESPIRATORY BURDEN CONTROL)

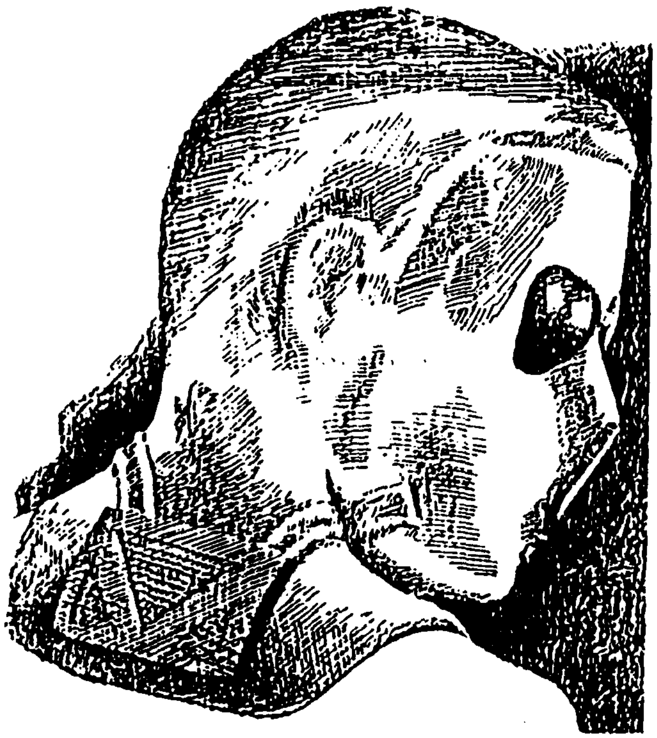
CP - PRESSURIZATION
CP - AUTOMATIC VALVING
C - CO2 ABSORPTION
CP - PRESSURE MICROSENSORS

- **COMMUNICATIONS** (SENSORY BURDEN CONTROL)

CP - AMPLIFIED RECEIVERS/TRANSMITTERS
CP - NETWORK COMMUNICATIONS
CP - IR COMMUNICATIONS
MP - DETECTOR INTERFACE

RESPO 21

CONCEPT #1



DESIGNATION: Softshell

COMPONENT TECHNOLOGIES:

POWER SUPPLY: None (Optional Blower)

FACEPIECE DESIGN: Conformal TPE Laminated Foam

AGENT PROCESSING: Low Profile, High Surface Area

COOLING: Heat/Moisture Absorbing Materials

RESPIRATORY: Low Dead Space Volume

OPTICS: Near Flat Optics (Laser or Correction Optional)

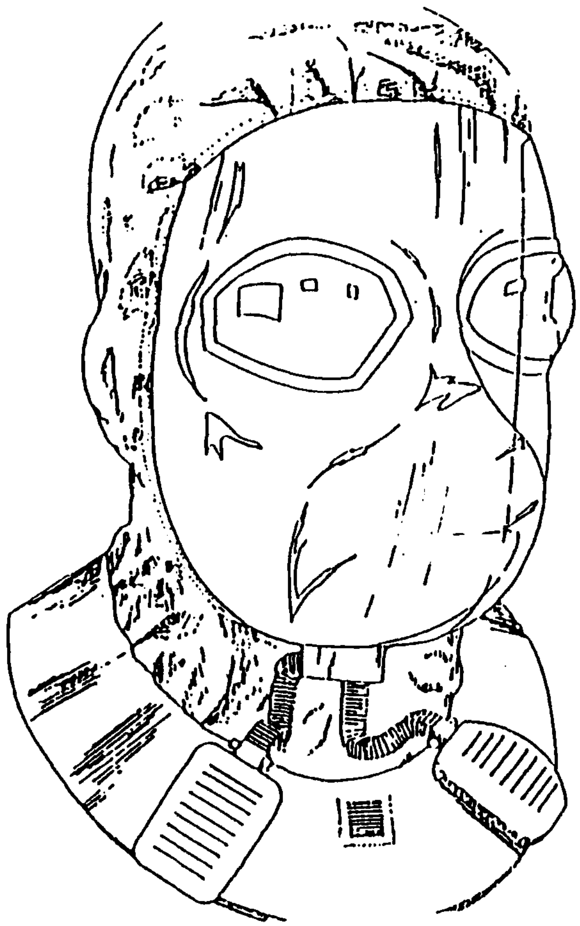
COMMUNICATIONS: Thin Film (Optional Electronics)

SEAL: Low Durometer Foam Liners

SPECIAL FEATURES: Disposable, Lightweight, Conformal

RESPO 21

CONCEPT #2



DESIGNATION: Semi-Rigid

COMPONENT TECHNOLOGIES:

POWER SUPPLY: Commo. Only (Optional Blower)

FACEPIECE DESIGN: Transparent Thermoset Copolymer

AGENT PROCESSING: Mobile Filter Cartridges

COOLING: Pre-Alert Venting/Removable Hood (Blower Op)

RESPIRATORY: Pre-Alert Low Resistance Filter/Valves

OPTICS: XM44 Type Lenses (Laser or Corrective Insert)

COMMUNICATIONS: Voice Amplification System

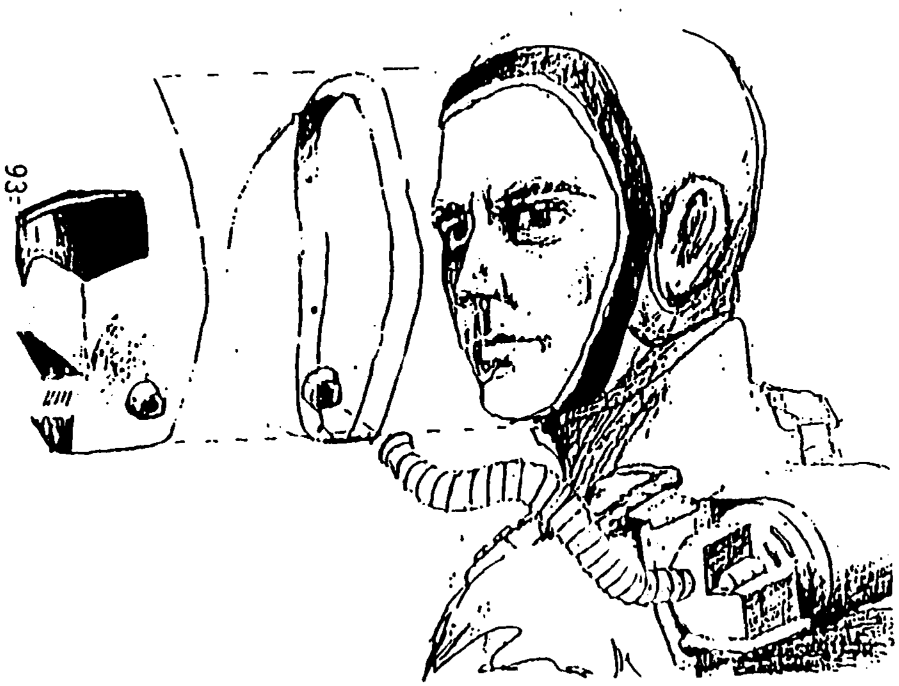
SEAL: Unimolded Low Durometer Bladder

SPECIAL FEATURES: Transparent, Self Adaptable

Potential for Replaceable Fluorocarbon Coating

RESPO 21

CONCEPT #3



DESIGNATION: Hardshell (Modular)

COMPONENT TECHNOLOGIES:

POWER SUPPLY: Lithium Thionyl Chloride

FACEPIECE DESIGN: Liquid Crystal or Polycarbonate

AGENT PROCESSING: Blower (Potential Electrostatics)

COOLING: Forced Air Convection

RESPIRATORY: Breathing Assist, Auto. Valving

OPTICS: B-LPS Design or Full Face Bubble

COMMUNICATIONS: Infrared (IR) or Local Network

SEAL: Pneumatic (Encapsulated Gel Back-up)

SPECIAL FEATURES: Modular Facepiece Design

Potential for Limited Fragment Protection

10.4 Appendix D

Chem/Bio Threat Overview

Presented By Mr. Charles R. Crawford

US Army CRDEC
ATTN: SMCCR-ST
APG, MD 21010-5423
(301) 671-3570
AV 584-3670

C. R. "CHUCK" CRAWFORD
STUDIES & ANALYSIS OFFICE
CRDEC

ADDRESS:

COMMANDER
U.S. ARMY CRDEC
ATTN: SMCCR-ST
APG, MD 21010-5423

PHONE:

AV 584-3570
COMM (301) 671-3570

THE MODERN BATTLEFIELD

- VIOLENT
- MOBILE

CHEMICAL-BIOLOGICAL WARFARE SPECTRUM

MUSTARD NERVE AGENTS CYANIDE	TOXIC INDUSTRIAL, PHARMACEUTICAL AND AGRICULTURAL CHEMICALS	PEPTIDES	SAXITOXIN MYCOTOXINS RICIN	MODIFIED TAILORED BACTERIA AND VIRUSES	BACTERIA VIRUSES RICKETTSIA
CLASSICAL CW	EMERGING CW	BIOREGULATORS	TOXINS	GENETICALLY MANIPULATED	TRADITIONAL BW

← AGENTS OF BIOLOGICAL ORIGIN → (Peptides through Bacteria/Viruses/Rickettsia)

← AGENTS NOT FOUND IN NATURE -- DESIGNER DRUG MODIFICATION → (Mustard through Saxitoxin/Mycotoxins/Ricin)

CHEMICAL AND BIOLOGICAL AGENTS

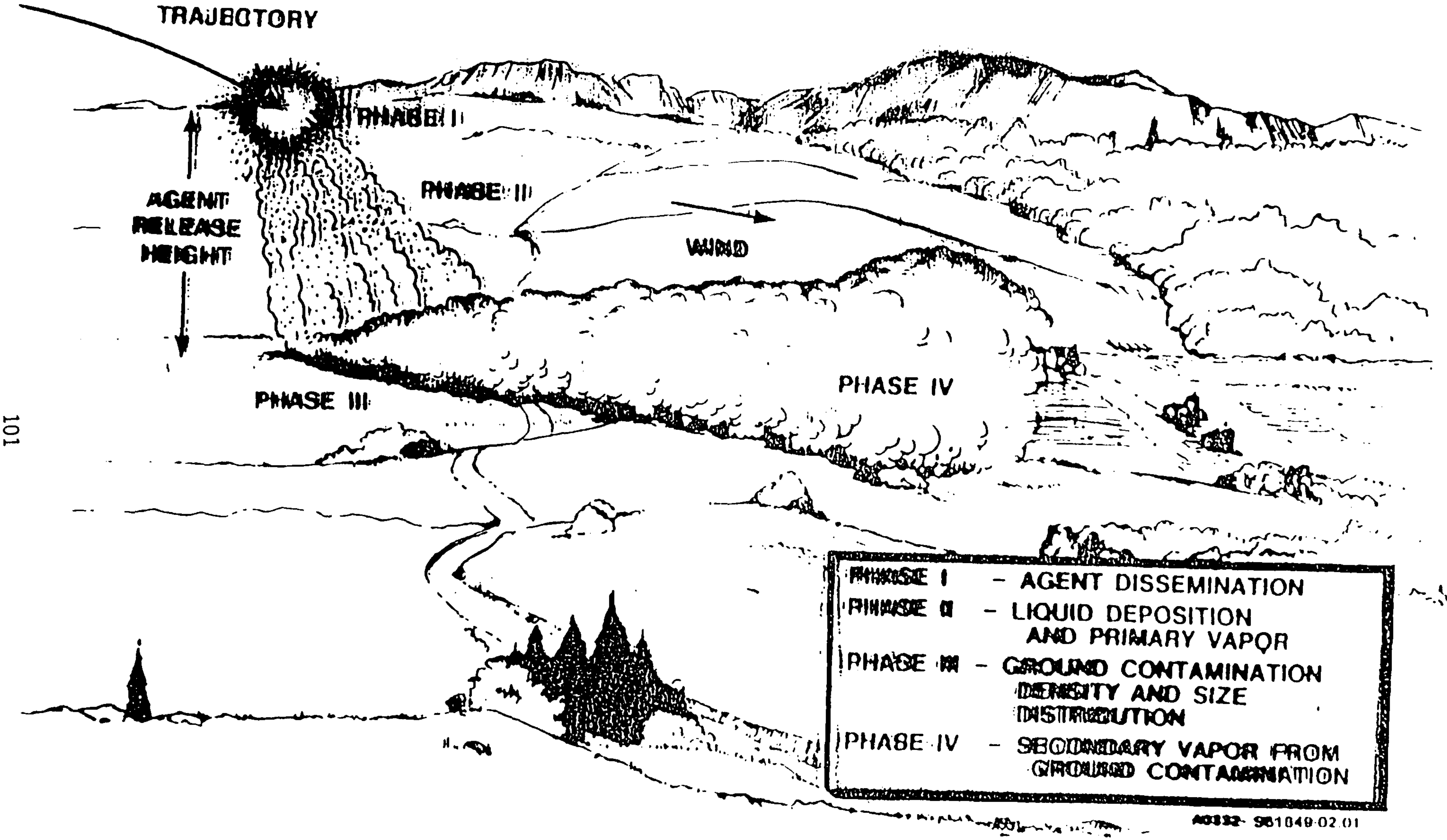
- SOLIDS
- LIQUIDS
- VAPORS

POTENTIAL DELIVERY SYSTEMS

- ARTILLERY
- ROCKET
- MISSILE
- BOMB
- AIRCRAFT SPRAY

SOLID DISSEMINATION

- SOLID POWDERS
- AEROSOLS
  - DISSOLVED
  - SLURRY


TRAJECTORY
AGENT RELEASE HEIGHT
PHASE I
PHASE II
WIND
PHASE III
PHASE IV
PHASE I - AGENT DISSEMINATION
PHASE II - LIQUID DEPOSITION AND PRIMARY VAPOR
PHASE III - GROUND CONTAMINATION DENSITY AND SIZE DISTRIBUTION
PHASE IV - SECONDARY VAPOR FROM GROUND CONTAMINATION

PERSISTENT AGENTS

- HIGH CONTAMINATION <=> LARGE DROPS
- LOW CONTAMINATION <=> SMALL DROPS
- TIME DEPENDS ON AGENT AND SURFACE

BIOLOGICAL AGENTS

- EXTENDED PERSISTENCY - SOME
- DECAY RATES LARGELY UNKNOWN
  - HUMIDITY
  - TEMPERATURE
  - SUNLIGHT

TOXINS

- DISSEMINATED AS CHEMICAL OR BIOLOGICAL
- SOME PERCUTANEOUSLY ACTIVE
- PRINCIPAL ENTRY INHALATION OR INGESTION

ON-TARGET AREA COVERAGE - LIQUID DEPOSITIONS

DEPOSITION (MG/M^2)	AREA (KM^2)	FRACTION OF TOTAL AREA ATTACKED*
1	4.9	.93
100	4.5	.85
500	2.8	.53
1000	1.6	.31
5000	.27	.05
10,000	.04	.007

* TOTAL AREA ATTACKED IS 5.3 KM^2.

ON-TARGET AREA COVERAGE - VAPOR DEPOSITIONS

DOSAGE ($MG\text{-}MIN/M^3$)	15 SEC AREA (KM^2)	FRACTION OF TOTAL AREA ATTACKED*	AREA FOR TOTAL TIME OF EXPOSURE (KM^2)	FRACTION OF TOTAL AREA ATTACKED*
1	6.2	.63	8.0	.82
35	2.8	.29	6.9	.70
70	2.1	.21	6.4	.65
100	1.6	.16	5.9	.60
500	.13	.02	1.2	.12
1000	.03	.003	.73	.07
5000	0	0	.06	.006
10,000	0	0	.002	.0002

*TOTAL AREA ATTACKED IS 9.8 KM^2.

PROTECTION FACTOR
(CHEMICAL)

14 - 20,000

PROTECTION FACTOR (BIOLOGICAL)

	LOW EXPOSURE	HIGH EXPOSURE
• TOXIN		
	100 MG/M**3	1 G/M**3
	20 - 40,000	200 - 400,000
• PATHOGEN		
	10,000 CELLS/L	1,000,000 CELLS/L
	5 - 5,000	500 - 500,000

WHAT?	WHEN?		HOW MUCH? (EXTENT OF CAPABILITY)	IPE CONSIDERATIONS
	TECHNOLOGY DEMONSTRATED	PROBABILITY OF FIELD DELIVERY CAPABILITY BY 2000		
*SUBSTANCES				
ANTIPROTECTIVE	YES	MEDIUM TO HIGH	EFFECTS AGAINST CURRENT IRPE ARE EXPECTED TO BE CASUALTY-PRODUCING OR LETHAL.	CURRENT RESPIRATORY VULNERABILITY IS TO FILTER. NON-RESPIRATORY EFFECTS UNCERTAIN. NEED BROADER FILTER CAPABILITY.
BIOENGINEERED/ GENETIC ENGINEERED	YES	MEDIUM	VERY UNCERTAIN - HIGH POTENTIAL FOR INCAP. & LETHAL EFFECTS - BOTH TOXIN AND PATHOGEN.	SMALL PARTICLES & VAPOR MAY DEFEAT FILTERS & PERMEABLE MATERIALS OR INFILTRATE SYSTEMS THAT ARE NOT CONTINUOUSLY AIRTIGHT.
ENDOGENOUS REGULATORS	YES	LOW? TO MEDIUM	ALSO VERY UNCERTAIN AT THIS TIME- HOLDS PROMISE FOR CAUSING BROAD RANGE OF EFFECTS FROM IRRITATING TO LETHAL AND AT LOW LEVELS OF EXPOSURE.	MAY REQUIRE NEW FILTERING CAPABILITY.

WHAT?	WHEN?		HOW MUCH? (EXTENT OF CAPABILITY)	IPE CONSIDERATIONS
	TECHNOLOGY DEMONSTRATED	PROBABILITY OF FIELD DELIVERY CAPABILITY BY 2000		
*FORMS FOR DELIVERY				
DUSTY	YES	HIGH	WILL REQUIRE SLIGHTLY HIGHER EXPOSURE LEVELS THAN AGENT WITHOUT DUST	WILL PROVIDE INHALABLE PARTICLES AND CHALLENGE THE AIR-TIGHT INTEGRITY OF IRPE (ALSO NON-RESP. IPE)
MICRO-ENCAPSU-LATION	YES	MEDIUM TO HIGH	MAY IMPROVE AGENT DELIVERY, AND EFFECTIVELY REDUCE EXPOSURE LEVELS TO PRODUCE EFFECTS FOR STAN-DARD AGENTS; MAY GIVE NEW "LIFE" TO AGENTS PREVIOUSLY REJECTED AS THREAT AGENTS.	IPE CONSIDERATIONS FOR M/E ARE SIMILAR TO DUSTY AGENTS. THE DIFFERENCE IS THAT THEY OFFER MUCH BROADER APPLICATION.

MODELS

- IPE PERFORMANCE

  NON-RESPIRATORY - ONE

  RESPIRATORY - NONE

- CLOUD DEVELOPMENT - SEVERAL

10.5 Appendix E

Future Compatibility Requirements

Presented By Mr. David M. Harrah

US Army HEL
ATTN: SLCHE-CC
APG, MD 21005
(301) 278-5926
AV 298-5926

US ARMY
LABORATORY COMMAND

HUMAN ENGINEERING LABORATORY

Future Compatibility Requirements for RESPO 21

David M Harrah
Close Combat Division
11 October 89

HUMAN ENGINEERING LABORATORY

Purpose

US ARMY
LABORATORY COMMAND

Provide an overview of the potential system interface problems that the RESPO 21 program will have to resolve.

Major Trends

HUMAN ENGINEERING LABORATORY

US ARMY
LABORATORY COMMAND

- Reduction in crew size
- Switch from direct sighting systems to displays; either helmet mounted displays or panel displays
- Greater emphasis on automation of tasks
- Greater emphasis on sustained operations
- Heavier "bullets" of all types
- Increased use of positive pressure
- Fix - Forward concept

Sources

HEL Detachments

- AVSCOM
- TACOM
- ARDEC
- BRDEC
- MICOM
- CECOM

HEL Liaison Offices

- AVN Center
- AIR Defense Center

Other

- HEL Armor Team
- HEL Individual Soldier Team
- M40 Mask Human Facors Summary
- Military Journals

Current Systems

Future Systems/Concepts

HUMAN ENGINEERING LABORATORY

US ARMY
LABORATORY COMMAND

Summary

- Integrated helmet systems will present the biggest challenge to RESPO 21
- Direct sighting systems will remain in the inventory
- Automation will relieve some of the burden of physiologically heavy tasks
- Workloads will increase in some mission areas; principally the infantry
- More of the burden for protecting vehicle operators will be placed on positive pressure systems; however, individual protection may still be required

10.6 Appendix F

Operational Priorities

Presented By Ms. Stephanie Clewer

US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-4204
AV 584-4204

INDIVIDUAL PROTECTIVE EQUIPMENT (IPE) USERS MEETING

NOVEMBER 1985

PARTICIPATING GROUPS:

- O GROUP I - COMBAT/COMBAT SUPPORT ACTIVITIES (MOBILE).

- O GROUP II - COMBAT SUPPORT/COMBAT SERVICE SUPPORT (SEMI-FIXED SIGHT).

- O GROUP III - FIXED SIGHT.

DISCREPANCIES AMONG GROUPS:

- LOGISTICS SUPPORTABILITY - IMPORTANCE DECREASED FROM GROUP I TO GROUP III DUE TO MOBILITY REQUIREMENTS.

- OPERATIONAL PARAMETERS: ENTRY/EXIT OF ENCLOSURES-RATED HIGHER BY NAVY AND ORDNANCE REPRESENTATIVES OF GROUP III DUE TO INCREASED COLLECTIVE PROTECTION SHELTERS IN FIXED SITE UNITS.

- USER SUSTAINABILITY: DRINKING PORT - RATED HIGHER BY GROUP III DUE TO LABOR INTENSIVE WORK OF LOGISTICS AND ORDNANCE.

- EQUIPMENT PARAMETERS: SIZE/BULK/WEIGHT - IMPORTANCE DECREASED WITH MOBILITY REQUIREMENTS FROM GROUP I TO GROUP III.

ORDERING OF PERFORMANCE FACTORS BY RELATIVE IMPORTANCE

*MODE SCORES

1. INDIVIDUAL PROTECTION
   1. TIME
   2. EFFECTIVENESS LEVEL
   3. THREAT LEVEL

2. MISSION PERFORMANCE
   1. VISION
   2. PHYSIOLOGICAL STRESS
   3. COMMUNICATIONS
   4. PSYCHOLOGICAL STRESS

3. OPERATIONAL PARAMETERS
   1. ENVIRONMENTAL HAZARDS
   2. COMPATIBILITY WITH GEAR
   3. ENTRY/EXIT
   4. COUNTERSURVEILLANCE

4. USER SUSTAINABILITY
   1. DRINKING
   2. FEEDING
   3. WASTE DISPOSAL
   4. MEDICAL ACCESSIBILITY

5. EQUIPMENT SURVIVABILITY
   1. RELIABILITY
   2. DECONTAMINABILITY
   3. AVAILABILITY
   4. DURABILITY
   5. HARDNESS
   6. MAINTAINABILITY
   7. CLEANABILITY

6. EQUIPMENT PARAMETERS
   1. SIZE/BULK/WEIGHT
   2. CONSUMABLES
   3. POWER REQUIREMENTS
   4. RESIDUAL LIFE INDICATOR
   5. INITIAL QUALITY INDICATOR

7. LOGISTICS SUPPORT
   1. FIELD SUPPORT
   2. STORAGE/SHELF LIFE
   3. TRAINING
   4. SPECIAL TOOLS

MISSION PERRFORMANCE DEGRADATION

BURDEN CHARACTERISTICS

- 0 RESPIRATORY BURDEN
- 0 THERMAL BURDEN
- 0 SENSORY BURDEN
  - 0 OPTICS
  - 0 COMMUNICATIONS
    - 0 SPEAKING
    - 0 HEARING
- 0 BIOMECHANICAL BURDEN
- 0 METABOLIC BURDEN
  - 0 MOISTURE REMOVAL
  - 0 DRINKING
  - 0 FEEDING
- 0 PSYCHOLOGICAL BURDEN

THREAT CHARACTERISTICS

- 0 CHEMICAL/BIOLOGICAL
- 0 BALLISTICS
- 0 NUCLEAR
  - 0 THERMAL
  - 0 FLASH
- 0 FLAME
- 0 DIRECTED ENERGY
  - 0 MICROWAVE, ETC
  - 0 LASER
- 0 ACOUSTICS/NOISE
- 0 ENVIRONMENTAL

MISSION PERFORMANCE DEGRADATION
PRELIMINARY USERS' SURVEY RESULTS

ORDERING OF BURDEN CHARACTERISTICS BY RELATIVE IMPORTANCE

ARMOR		INFANTRY	
1.	OPTICS	1.	OPTICS
2.	SPEAKING	2.	RESPIRATORY BURDEN
3.	RESPIRATORY BURDEN	3.	THERMAL BURDEN
4.	HEARING	4.5.	SPEAKING
5.	THERMAL BURDEN	4.5.	BIOMECHANICAL BURDEN
6.	DRINKING	6.	HEARING
7.	BIOMECHANICAL BURDEN	7.	DRINKING
8.	FEEDING	8.	PSYCHOLOGICAL BURDEN
9.	PSYCHOLOGICAL BURDEN	9.5.	FEEDING
10.	MOISTURE REMOVAL	9.5.	MOISTURE REMOVAL

MISSION PERFORMANCE DEGRADATION

PRELIMINARY USERS' SURVEY RESULTS

ORDERING OF THREAT CHARACTERISTICS BY RELATIVE IMPORTANCE

ARMOR		INFANTRY	
1.	CHEMICAL/BIOLOGICAL	1.	CHEMICAL/BIOLOGICAL
2.	FLAME	2.5.	THERMAL
3.	THERMAL	2.5.	FLASH
4.5.	BALLISTICS	4.	FLAME
4.5.	LASER	5.	BALLISTICS
6.	FLASH	6.5.	LASER
7.	MICROWAVE, ETC.	6.5.	MICROWAVE, ETC.
8.	ENVIRONMENTAL	8.	ENVIRONMENTAL
9.	ACOUSTICS/NOISE	9.	ACOUSTICS/NOISE

10.7 Appendix G

Physiological Requirements

Presented By Dr. Ronald A. Weiss

US Army CRDEC
ATTN: SMCCR-PPI
APG, MD 21010-5423
(301) 671-2313
AV 584-2313

PULMONARY FUNCTION

- UNBLOWN MODE

  -MAXIMUM VOLUNTARY VENTILATION: 240 LITERS/MINUTE

  -PEAK INSPIRATORY FLOW: 480 LITERS/MINUTE

  -PEAK EXPIRATORY FLOW: 960 LITERS/MINUTE

  -INLET RESISTANCE: 30 MM H_2O AT FLOW RATES TO 160 LITERS/ MINUTE

  -OUTLET RESISTANCE: 15MM H_2O AT FLOW RATES TO 160 LITERS/MINUTE

  -MASK DEAD SPACE: < 250 CUBIC CENTIMETERS

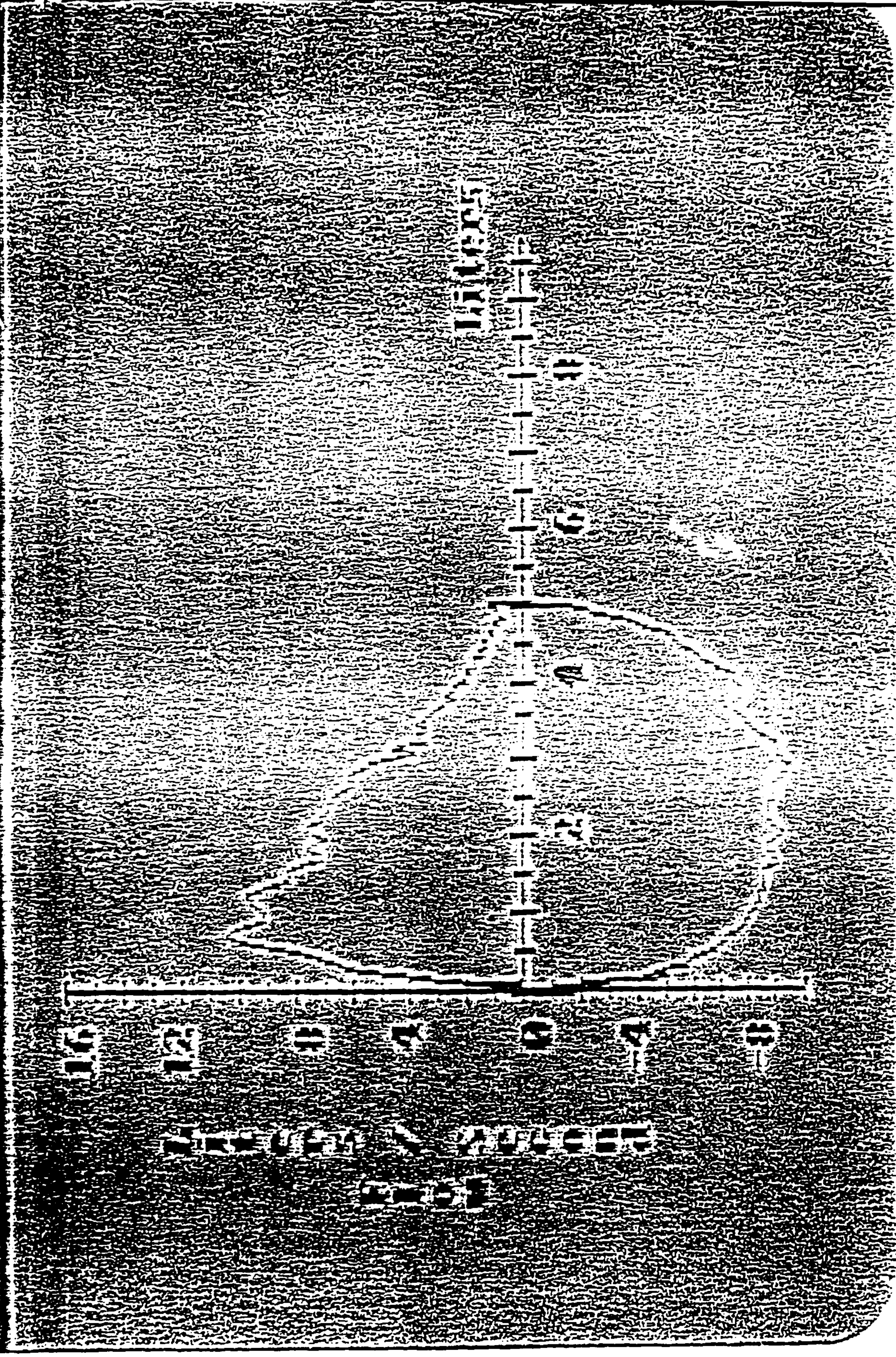
  -RETAINED CARBON DIOXIDE NOT TO EXCEED 2.0 PERCENT AT REST DURING INHALATION.

- FLOW PATH/NOSE CUP DESIGN CONSIDERATIONS

PULMONARY FUNCTION

- BLOWN MODE

  - AIR TEMPERATURE > 40 AND < 100 F
  - INHALED CARBON DIOXIDE: < 0.5%
  - INHALED OXYGEN: > 14%
  - FLOW RATE CONSIDERATIONS



VISION

PERIPHERAL FIELD: 200°

FIELD OF GAZE: 240°

BINOCULAR FIELD: HEIGHT: 100°

WIDTH: 120°

BELOW HORIZON ANGLE: 45°

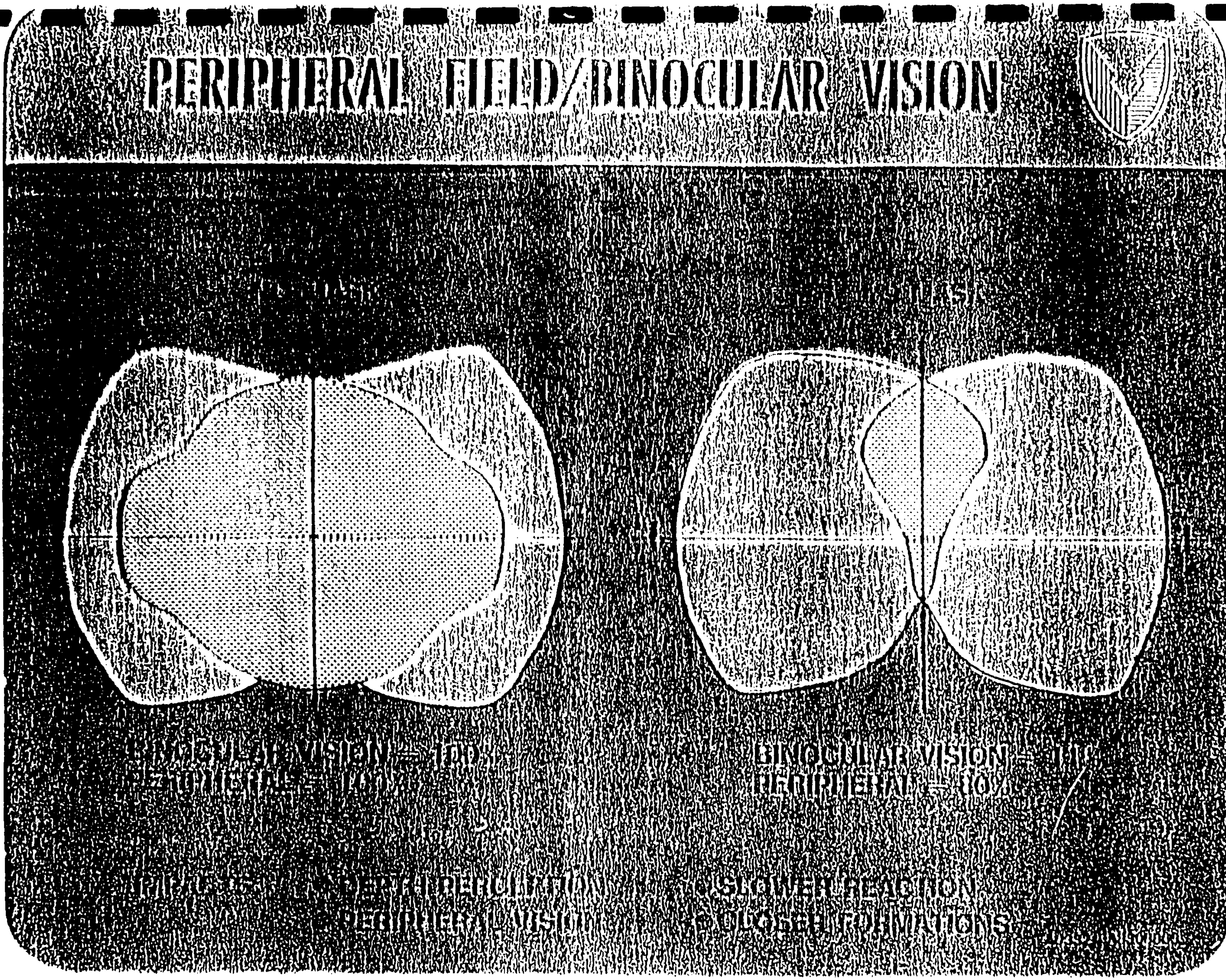
ESTERMAN FIELD: 100%

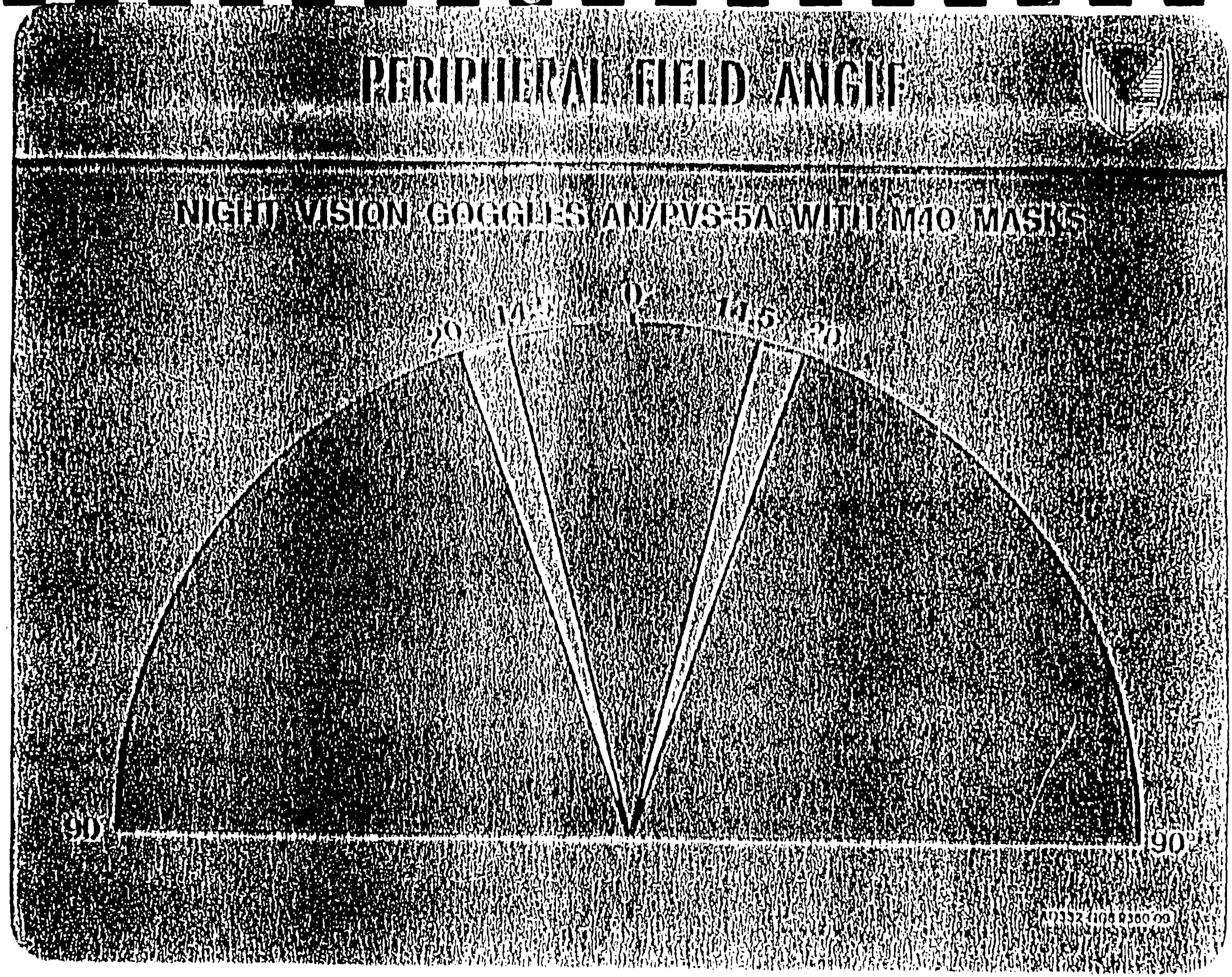
DEPTH PERCEPTION (FRISBY TEST) : 1MM

NEAR POINT FOCUS: NOT TO EXCEED 20 CM

INTERPUPILLARY DISTANCE: 50-80MM

EYE RELIEF: 13-20 MM UNIFORM ACROSS LENS


PERIPHERAL FIELD/BINOCULAR VISION
SLOWER REACTION
CLOSER FORMATIONS


PERIPHERAL FIELD ANGLE
NIGHT VISION GOGGLES AN/PVS-5A WITH M40 MASKS
20
0
14.5
20
90
90°

VISION

INHERENT REFRACTION: $\pm$ 0.12 DIOPTER

COLOR DISTORTION: NONE

HAZE: $<$ 2%

LIGHT TRANSMISSION

GLARE

DEVIATION: NONE

COMMUNICATIONS

- SPEECH

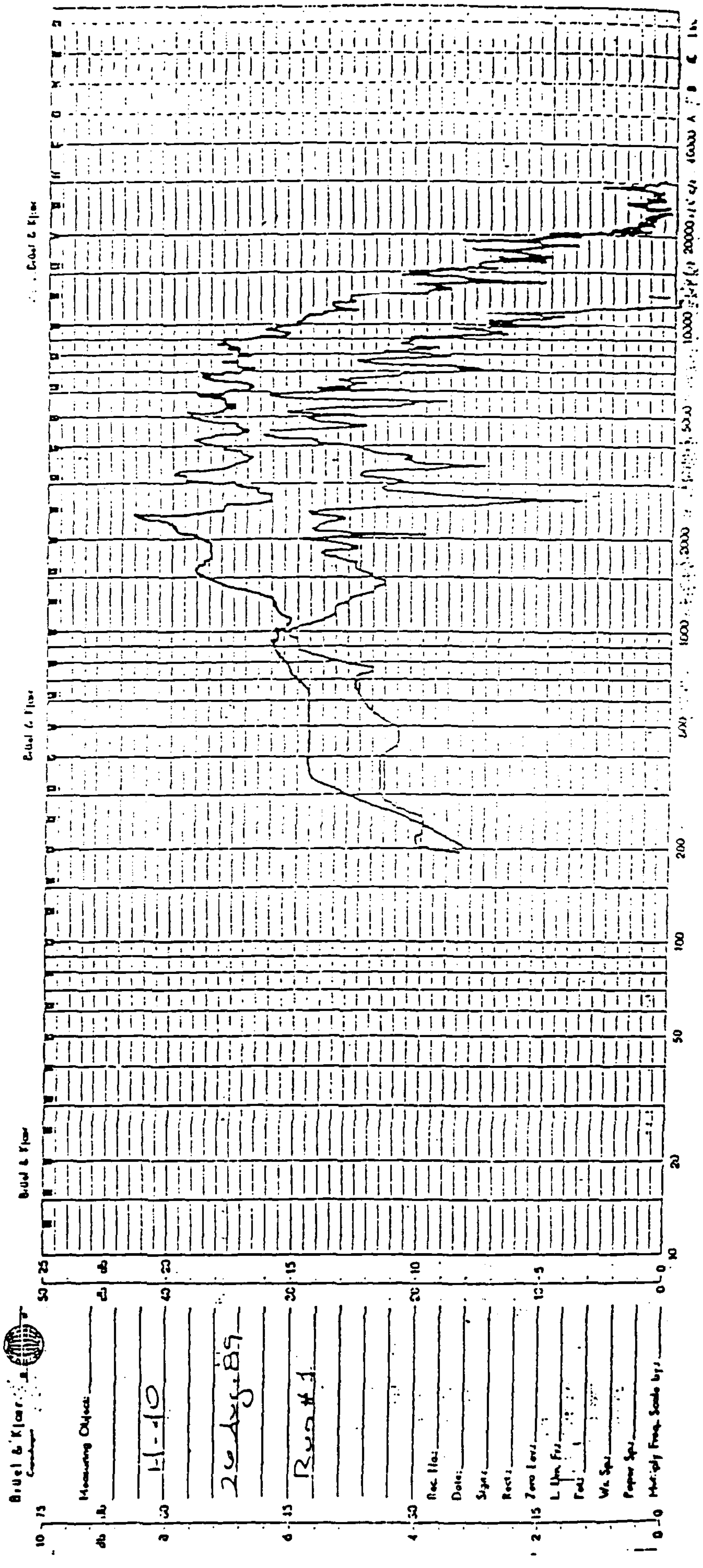
RAPID SPEECH INTELLIGIBILITY INDEX: › 0.85 THROUGH 85dB BACKGROUND NOISE.

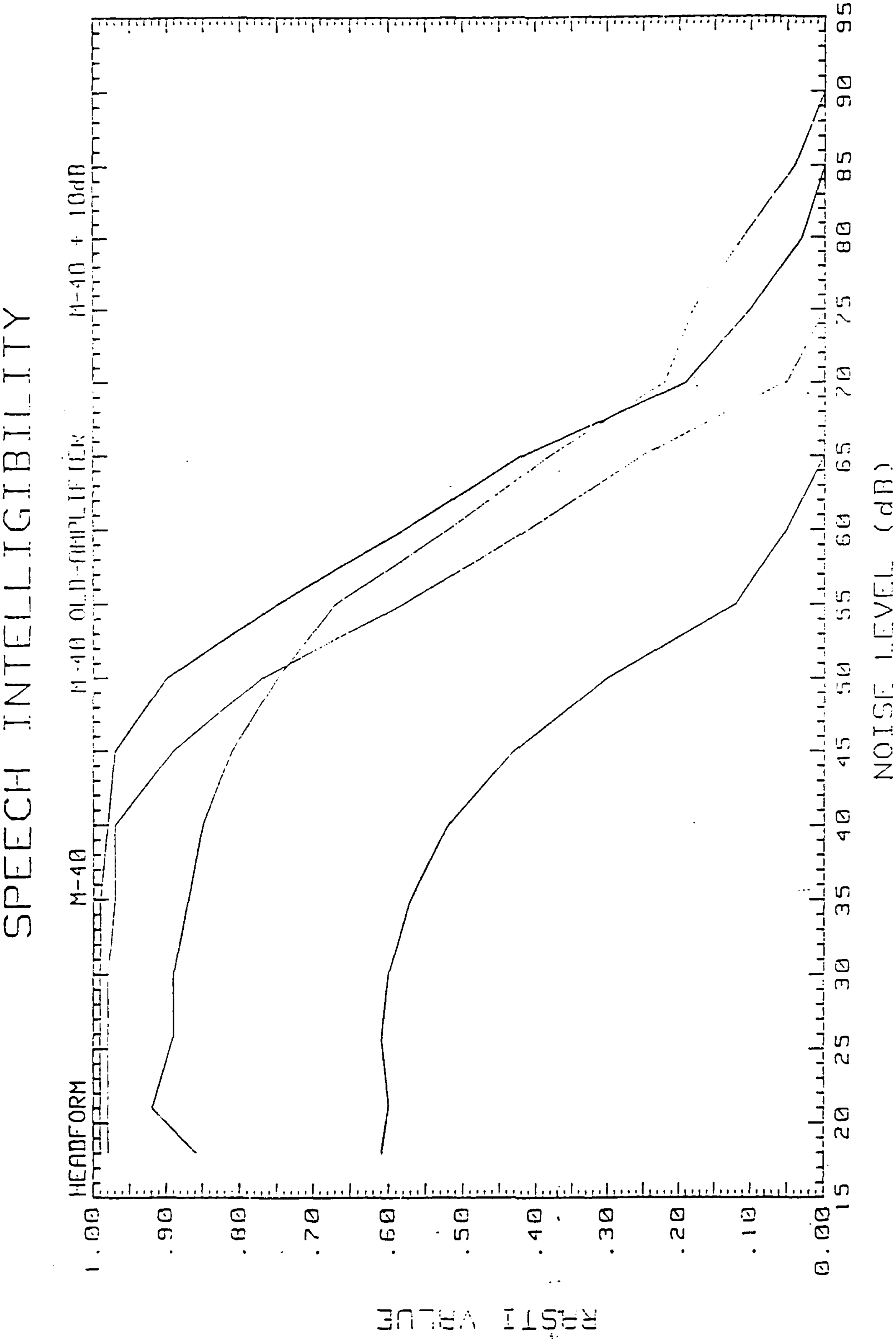
: VOWELS AND CONSONANTS SHOULD HAVE EQUAL CLARITY

PURE TONE FREQUENCY RANGE: 150 - 12,000 Hz ESSENTIAL

SIGNAL TO NOISE RATIO: AS HIGH AS POSSIBLE

REVERBERATION DECAY TIME: 0.2 MILLISECONDS OR LESS


Brüel & Kjær
Measuring Object:
H-10
26 Aug 89
Run #1
Rec. No.:
Date:
Sign.:
Rect.:
Zero Level:
L. Lim. Freq.:
Pot.:
Wr. Speed:
Paper Speed:
Multiply Freq. Scale by:
10
20
50
100
200
500
1000
2000
5000
10000
20000


SPEECH INTELLIGIBILITY
HEADFORM
M-40
M-40 OLD-AMPLIFIER
M-40 + 10dB
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0.00
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
NOISE LEVEL (dB)
RASTI VALUE

COMMUNICATIONS

SOUND ATTENUATION DISTANCE 3 dB DROP FACING FORWARD: › 5 METERS WITH VOICE AT 50 dB BACKGROUND NOISE

› 5 METERS WITH SHOUTING VOICE AT 85 dB BACKGROUND NOISE
10 dB DROP TO SIDE (TELEPHONE) › 20 CENTIMETERS

ATTENUATION CONTOUR: ›60 EITHER SIDE OF FACE FORWARD ESSENTIAL

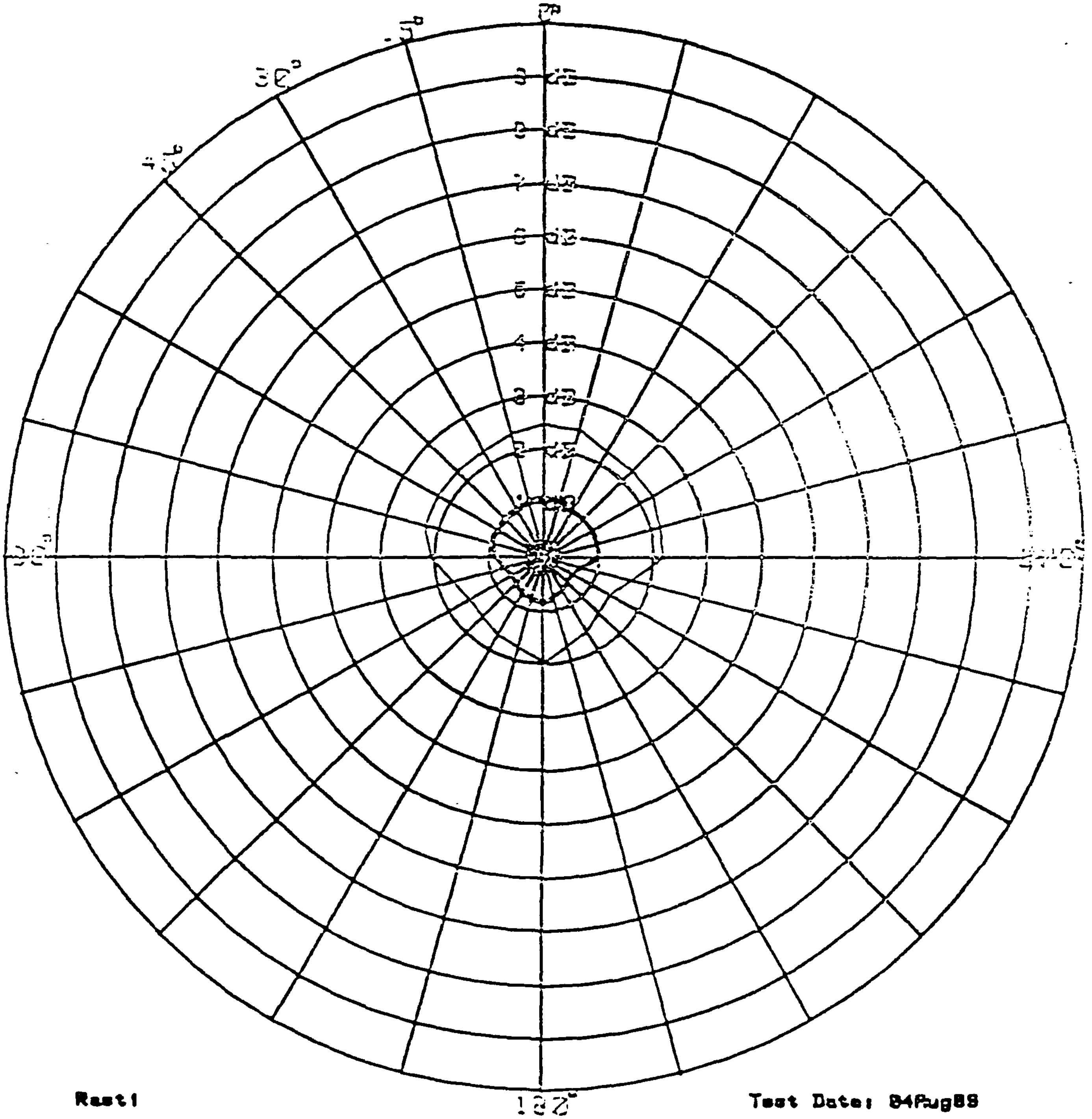
›100 EITHER SIDE OF FACE FORWARD DESIRABLE

AMPLIFICATION: 3dB ATTENUATION AT 10 METERS WITH 95dB BACKGROUND NOISE.

- NOSE CUP/CANISTER/INCLUSIONS/MOUNTING CONSIDERATIONS IN RESPIRATOR DESIGN.
- MOISTURE AS VOICEMITTER PROBLEM.
- HEARING: HOOD MATERIAL SHOULD NOT EXCEED 10dB ATTENUATION

RASTI

M-8 Mask with 8 dB Sound Pressure and Turntable Control



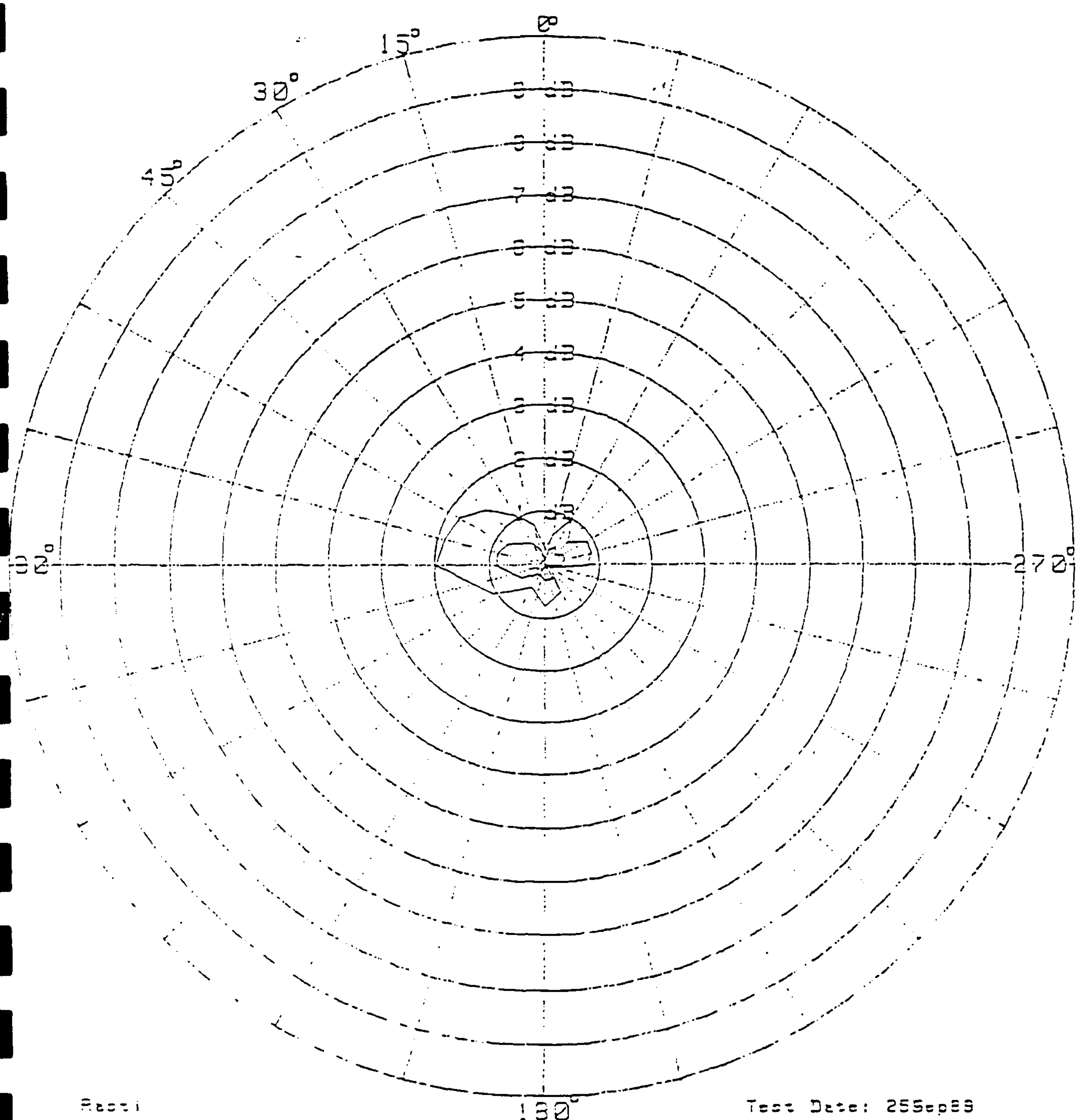
Rasti
500 Hz
2k Hz

Test Date: 04Aug88

Microphone distance 2 M

RASTI

British S-10 with eye piece inset and with canister.



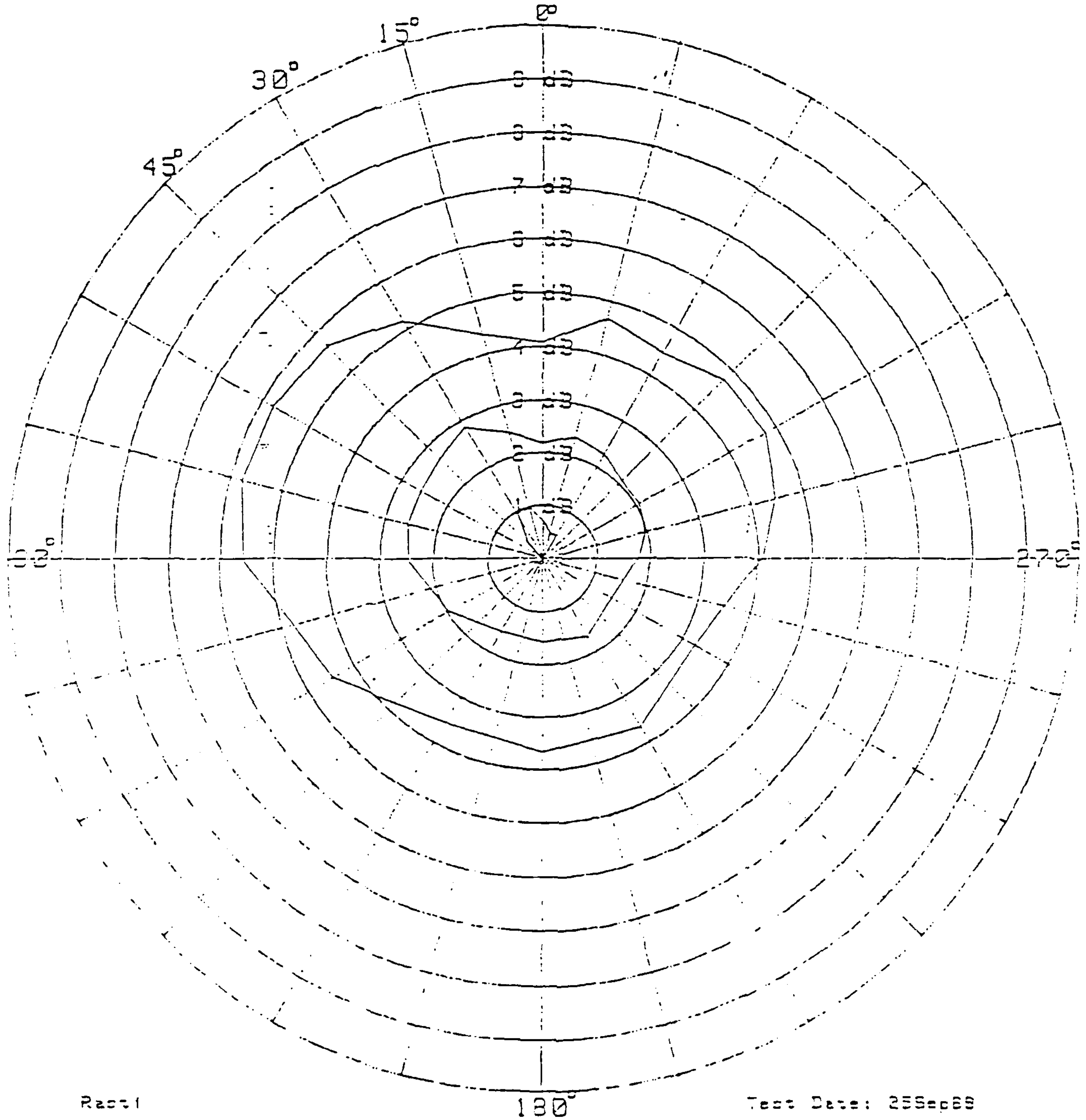
Rasti
500 Hz
2k Hz

Test Date: 25Sep89

Microphone distance 2 M

RASTI

British S-10 with eye piece inset and with canister.



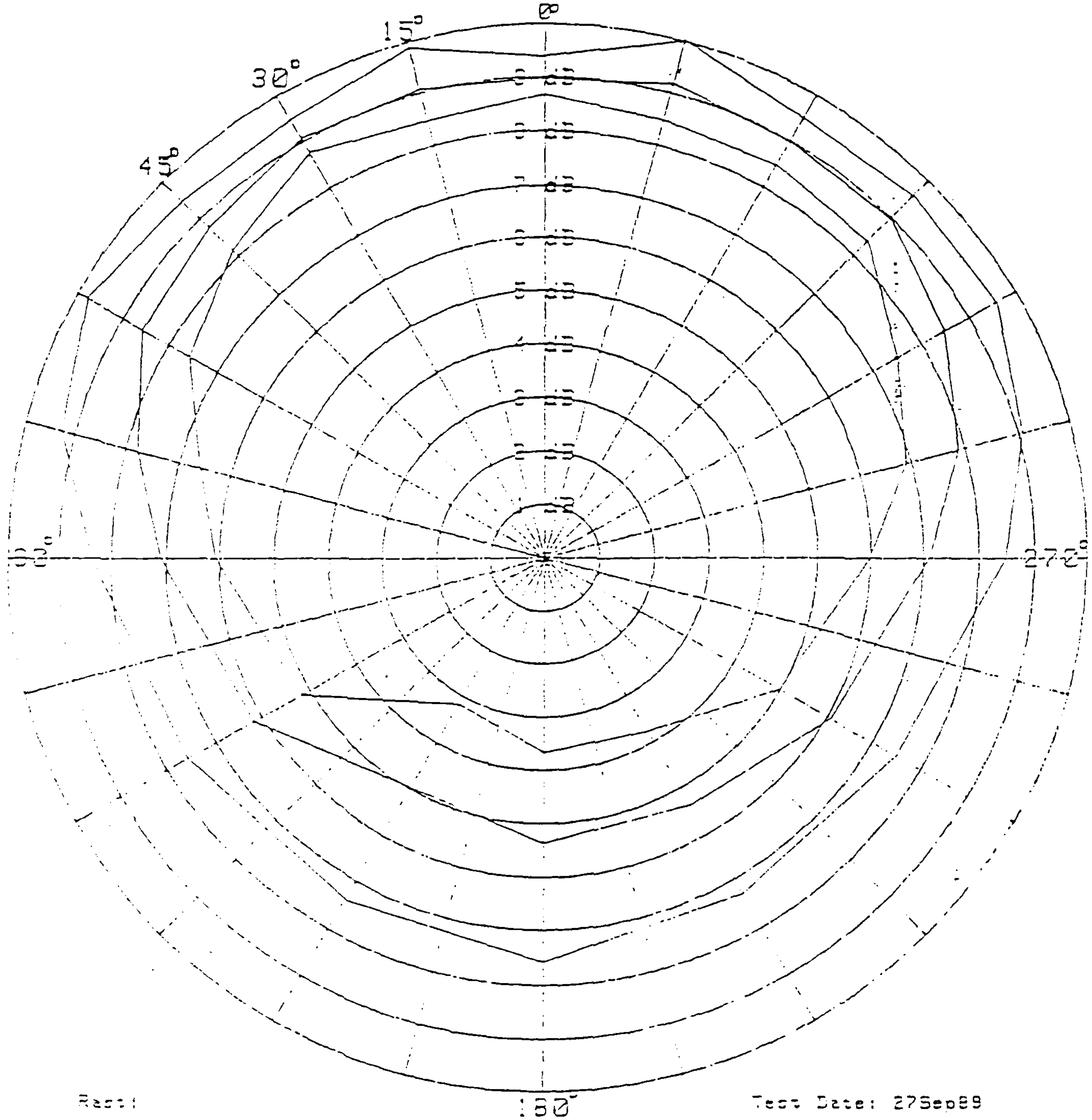
Rasti
500 Hz
2k Hz

Test Date: 25Sep88

Microphone distance 0.5 M

RASTI

HEADFORM



Rasti
500 Hz
2k Hz

Test Date: 27Sep89

Microphone distance 0.5 M

HUMAN FACTORS CONSIDERATIONS

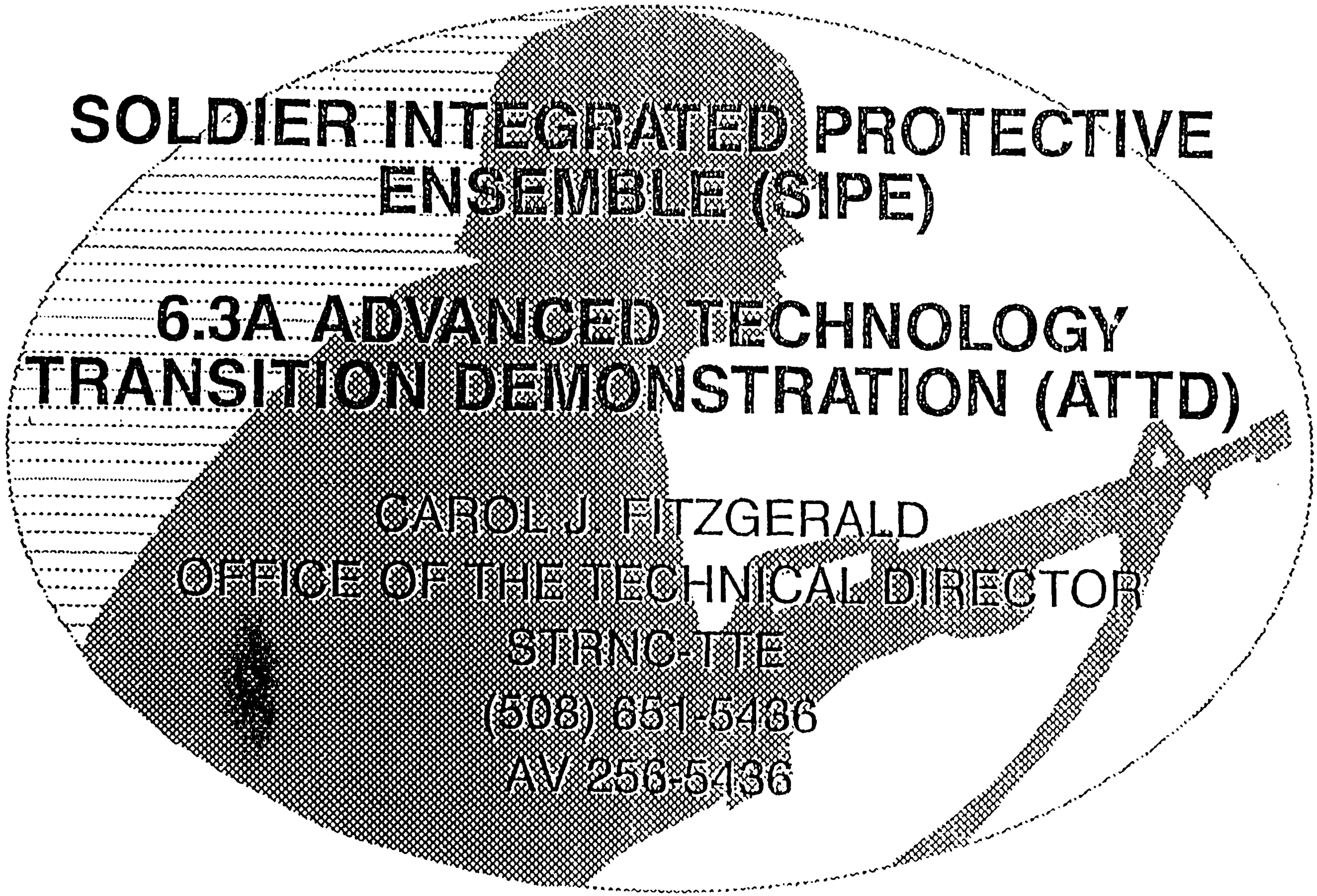
- DRINKING/NUTRITION
- HEAT STORAGE
- BLOOD CIRCULATION RESTRICTION
- SWEAT CONTROL
- BIOMECHANICS OF STRAPPING/JAW MOVEMENT/MUSCLE FATIGUE
- INTERFERENCE WITH OTHER EQUIPMENT
- COMBAT EFFECTIVENESS
  - PERSONNEL IDENTIFICATION
  - GIVING POSITION AWAY
  - SIGHTING RIFLES

10.8 Appendix H

Soldier Integrated Protective Ensemble, SIPE Overview

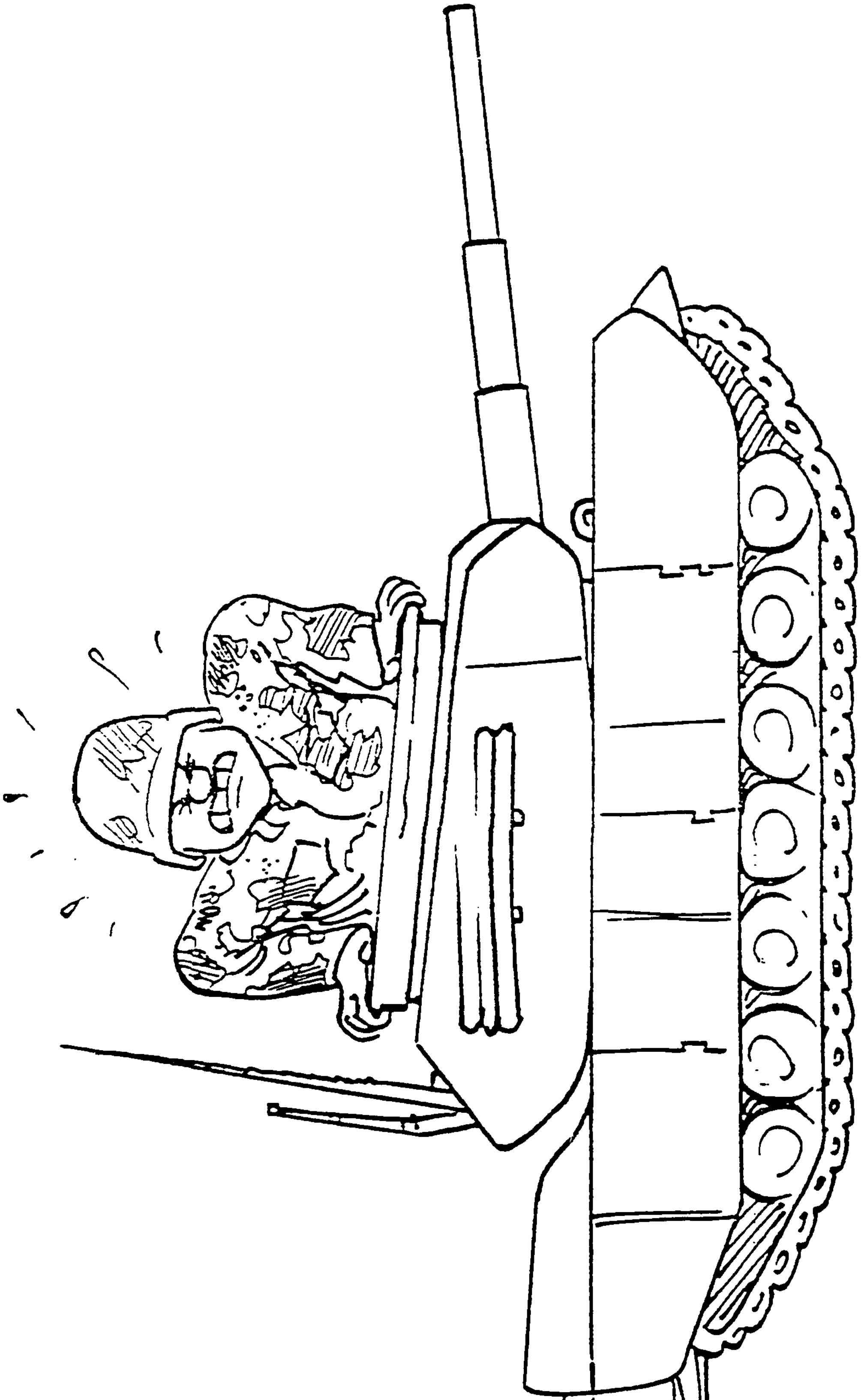
Presented By Ms. Carol J. Fitzgerald

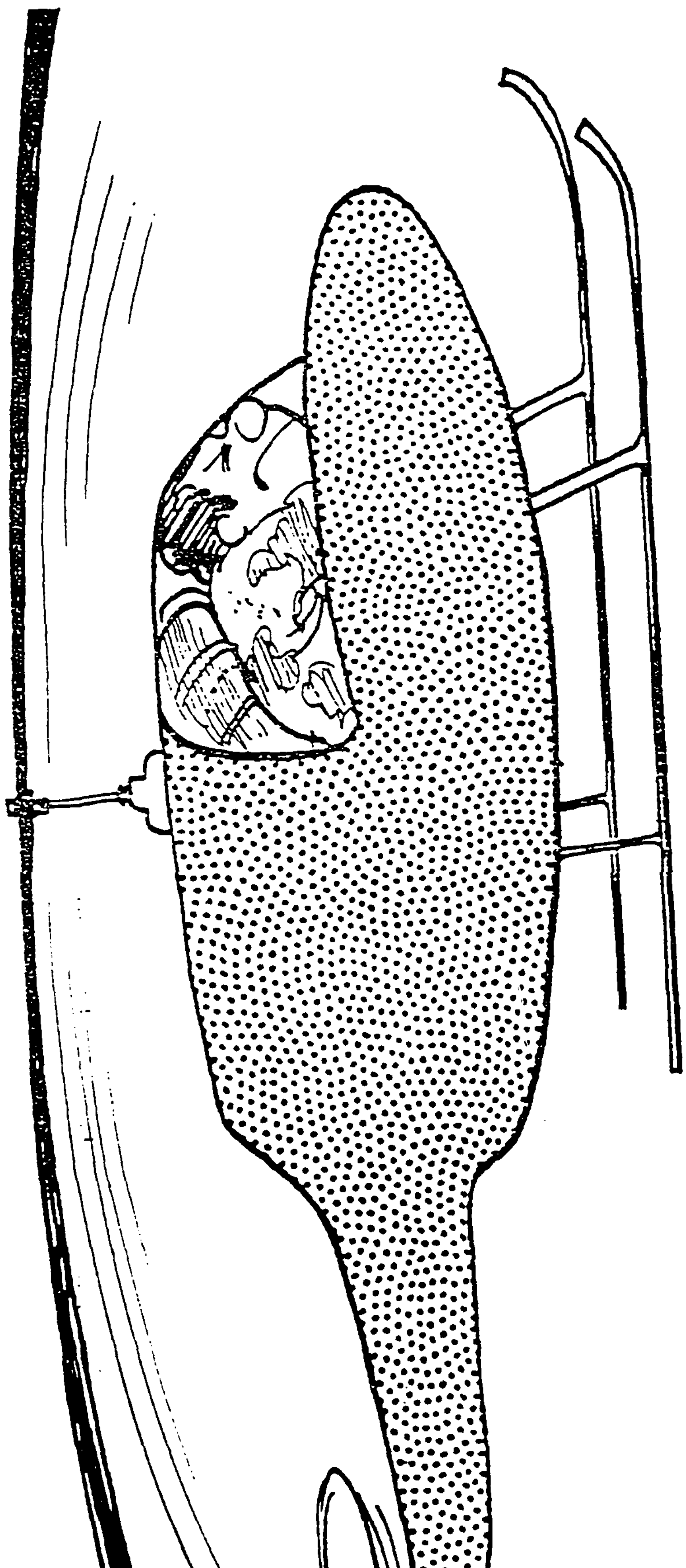
US Army NRDEC
ATTN: STRNC-TTE
Natick, MA 01760
(508) 651-5436
AV 256-5436

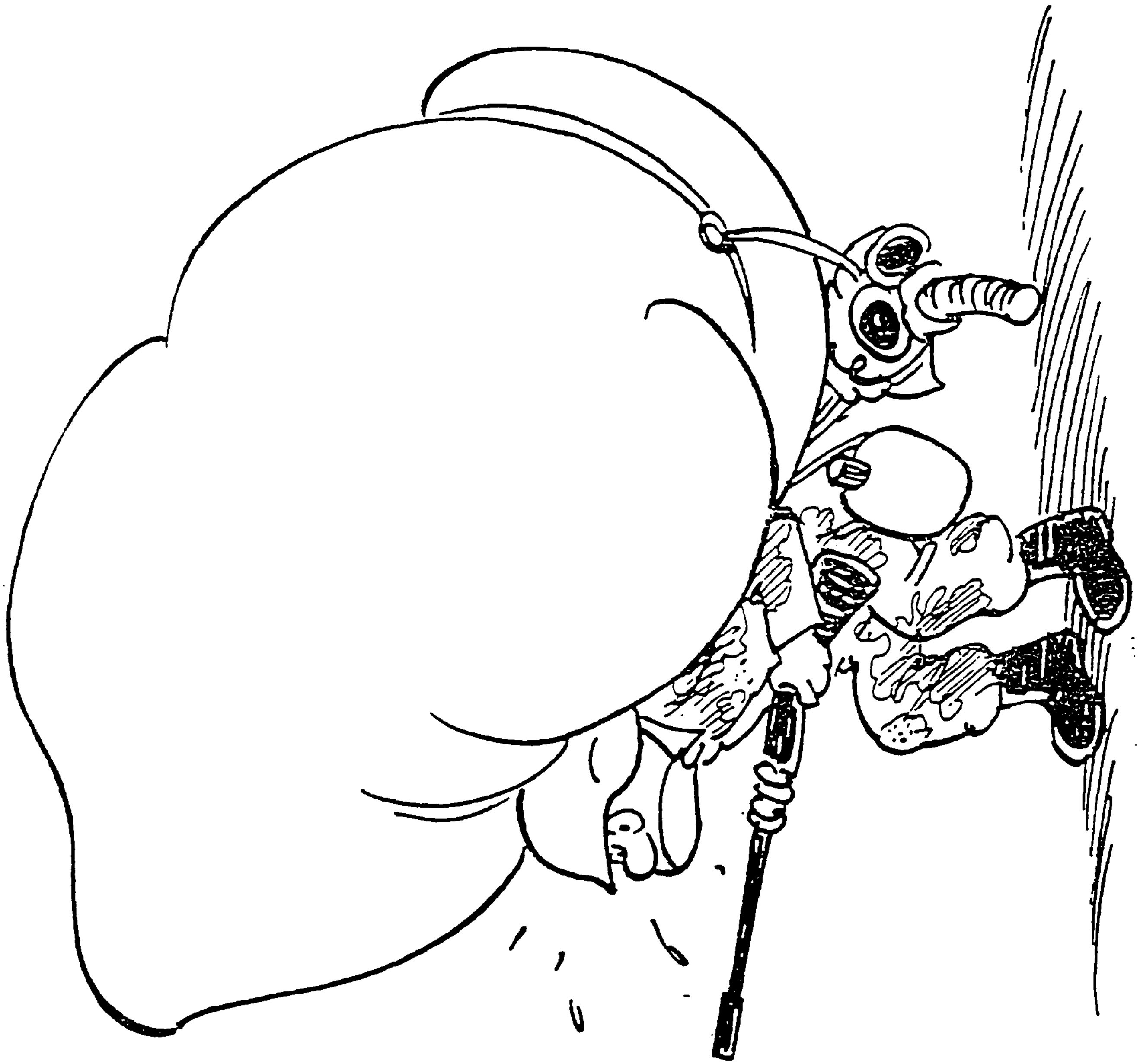

SOLDIER INTEGRATED PROTECTIVE ENSEMBLE (SIPE)
6.3A ADVANCED TECHNOLOGY TRANSITION DEMONSTRATION (ATTD)
CAROL J. FITZGERALD
OFFICE OF THE TECHNICAL DIRECTOR
STRNC-TTE
(508) 651-5436
AV 256-5436

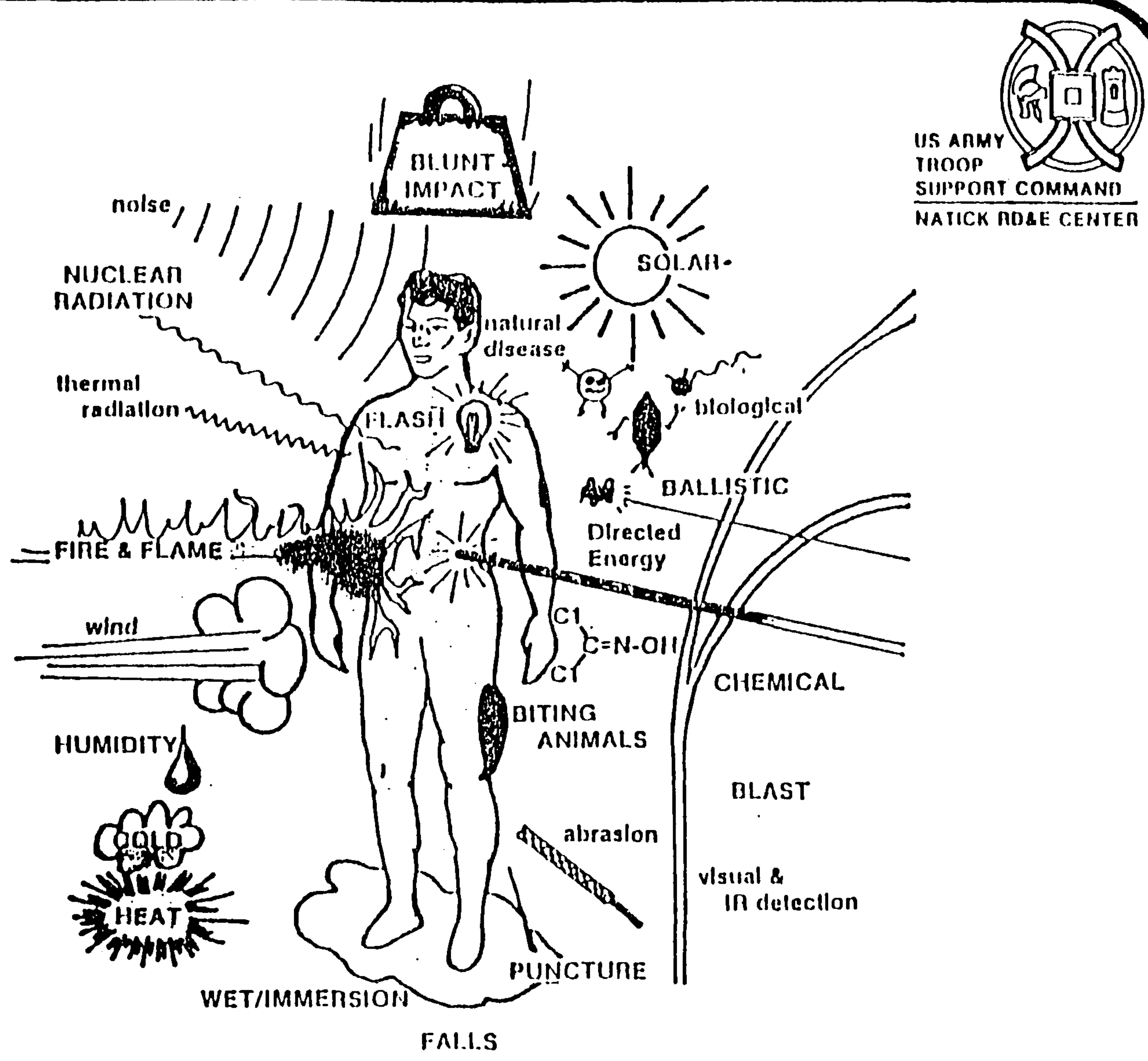
The Soldier Is A System

Why?









BATTLEFIELD THREATS AND HAZARDS

THE SOLDIER IS A SYSTEM

US ARMY
TROOP
SUPPORT COMMAND
NATICK RD&E CENTER

FOOD & WATER

CLIMATIC PROTECTION

WEAPONS & AMMUNITION

LASER PROTECTION

LOAD CARRYING EQUIPMENT

COMMUNICATIONS

BALLISTIC PROTECTION

NBC PROTECTION

COUNTER-SURVEILLANCE

NIGHTVISION DEVICES

DECISION SUPPORT

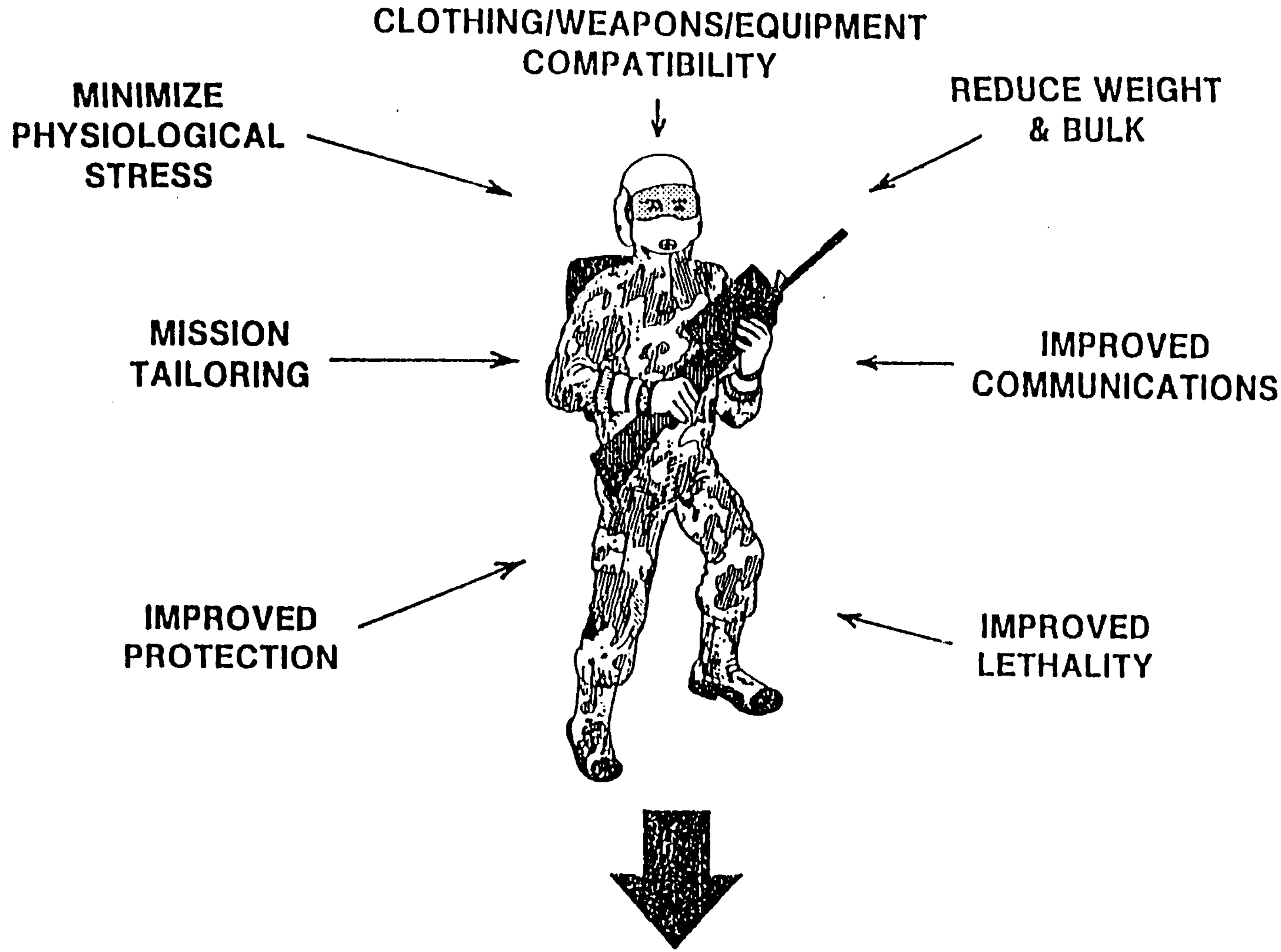
THE MOST IMPORTANT SYSTEM IN THE ARMY

The Soldier Is A System

Objectives

- Improved combat effectiveness
- Improved survivability & sustainability
- Lighten the load
- Synergism

SYNERGISM



IMPROVED COMBAT EFFECTIVENESS

SIPE

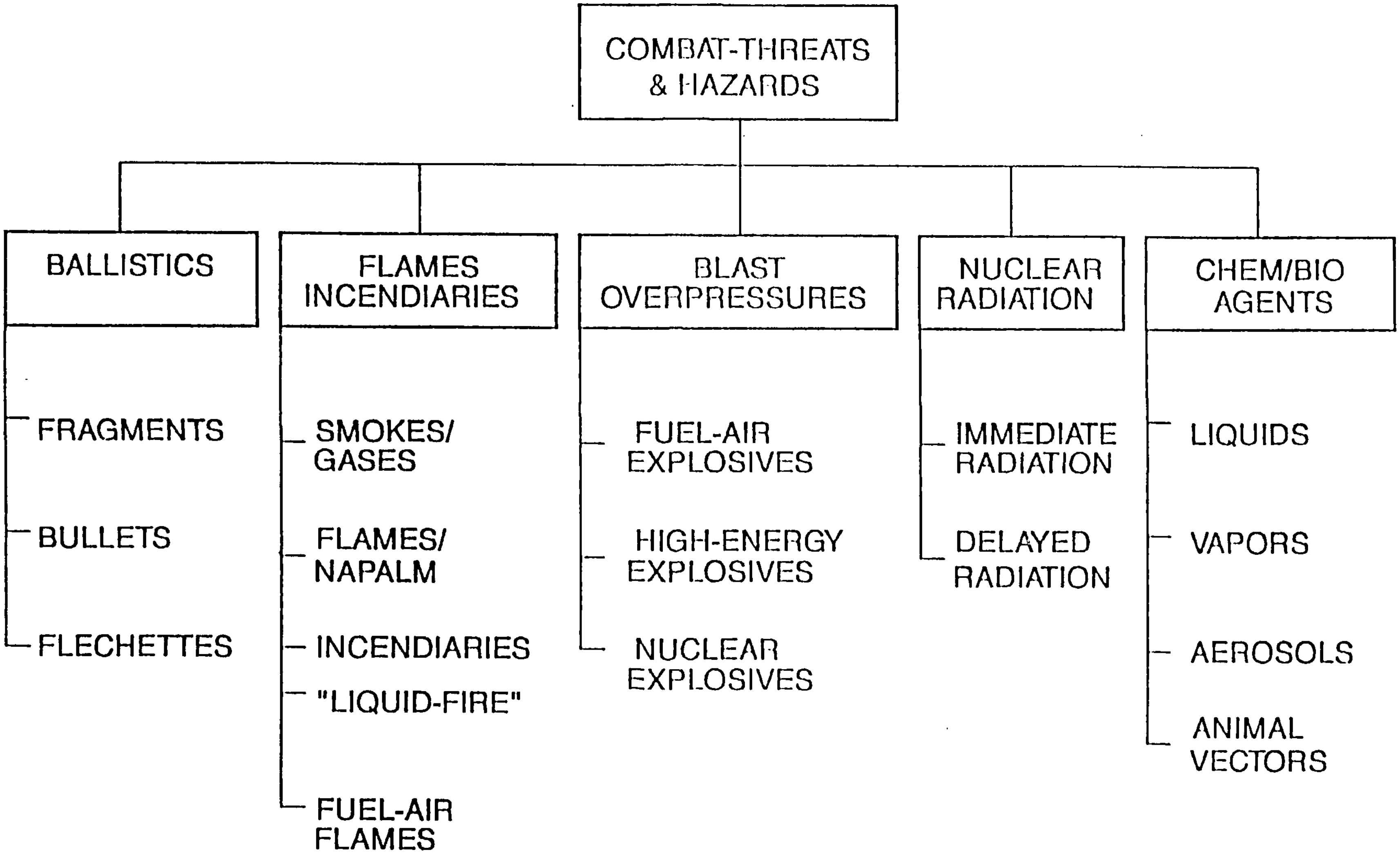
6.3A Advanced Technology Transition Demo (ATTD)

SIPE 6.3A Tech Demo

Objective

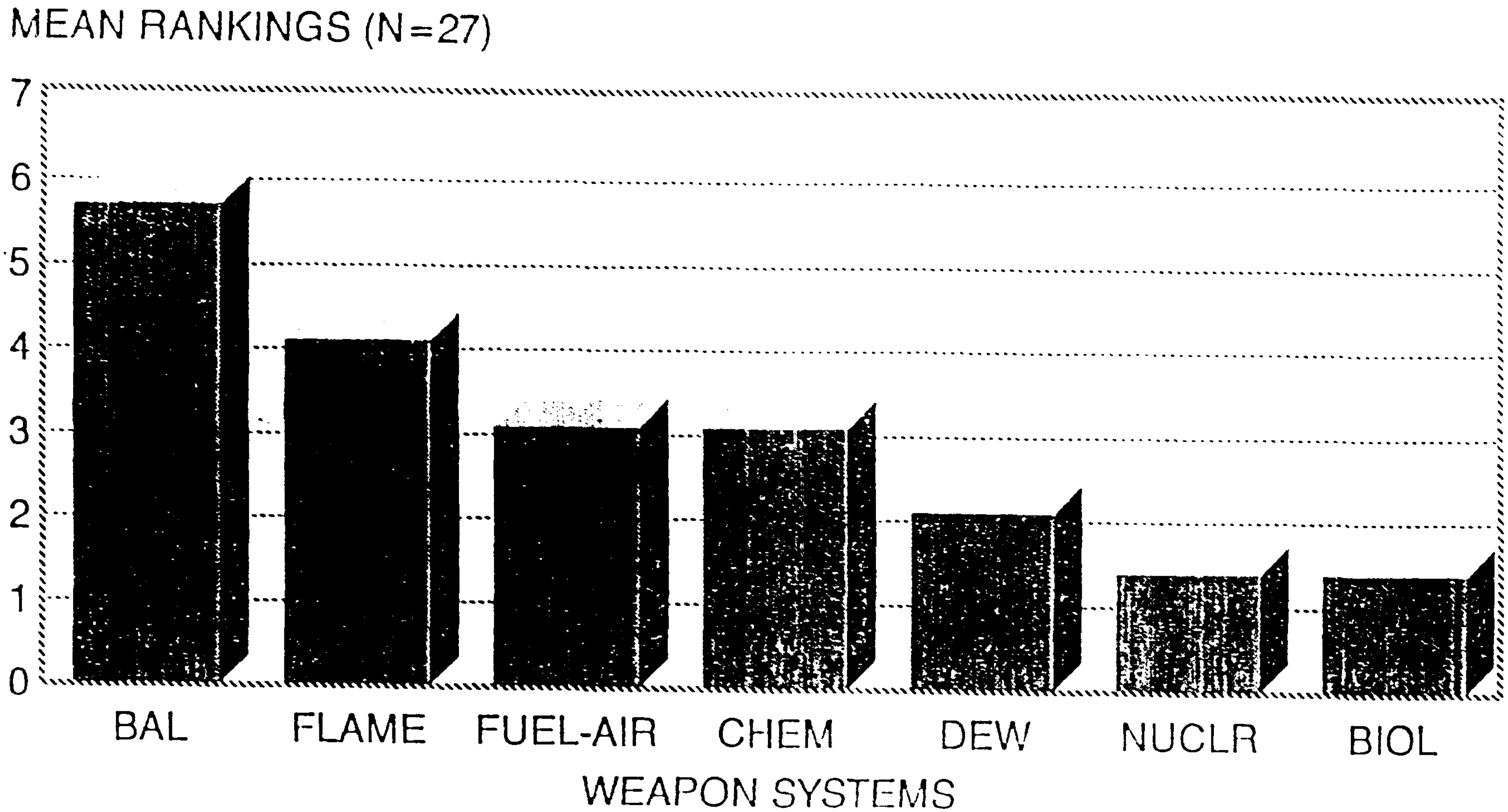
- To develop, fabricate and evaluate a prototype modular head-to-toe individual fighting system which will afford improved combat effectiveness while providing the individual soldier balanced protection against multiple battlefield threats/hazards.

POTENTIAL THREATS/HAZARDS



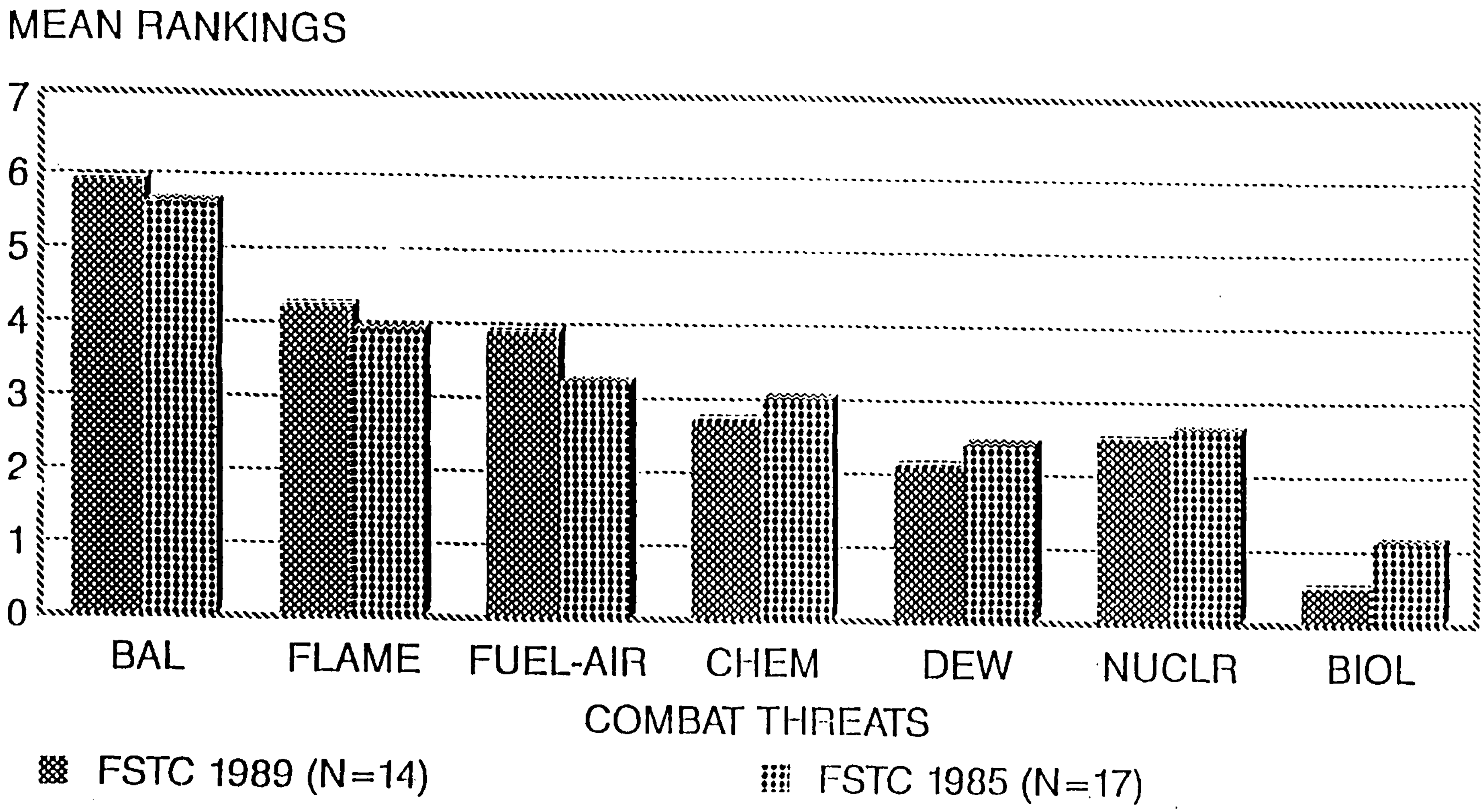
FSTC/FIO & CAC INTELLIGENCE ANALYSIS

RELATIVE IMPORTANCE OF FUTURE THREATS



RELATIVE IMPORTANCE OF FUTURE THREATS COMPARING FSTC

1989 VS. 1985



SIPE 6.3A Tech Demo

Multiple Threat Protection

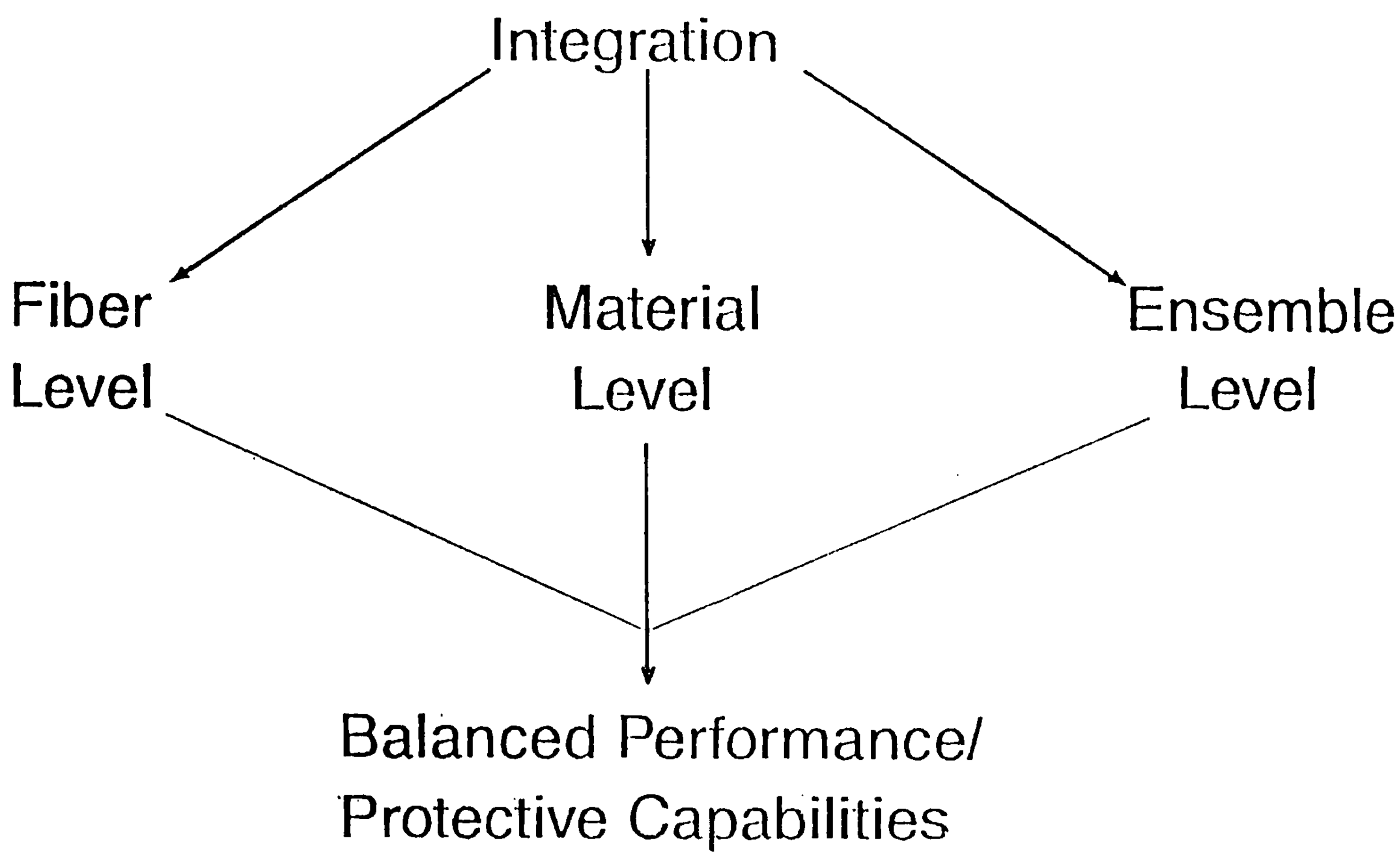
- Ballistic
- Chemical/Biological
- Flame/Nuclear Thermal
- Surveillance
- Environmental/Heat Stress
- Directed Energy
- Acoustic

SIPE 6.3A Tech Demo

Subsystems

- Integrated Headgear Systems
  - Respiratory Protection Included
  - Communications Capabilities
  - Improved Weapons Interface/Linkage
- Microclimate Conditioning
- Advanced Clothing Systems
- Advanced Handwear
- Advanced Footwear

SIPE 6.3A Tech Demo



SIPE 6.3A Tech Demo

Integration at the Fiber and Material Level

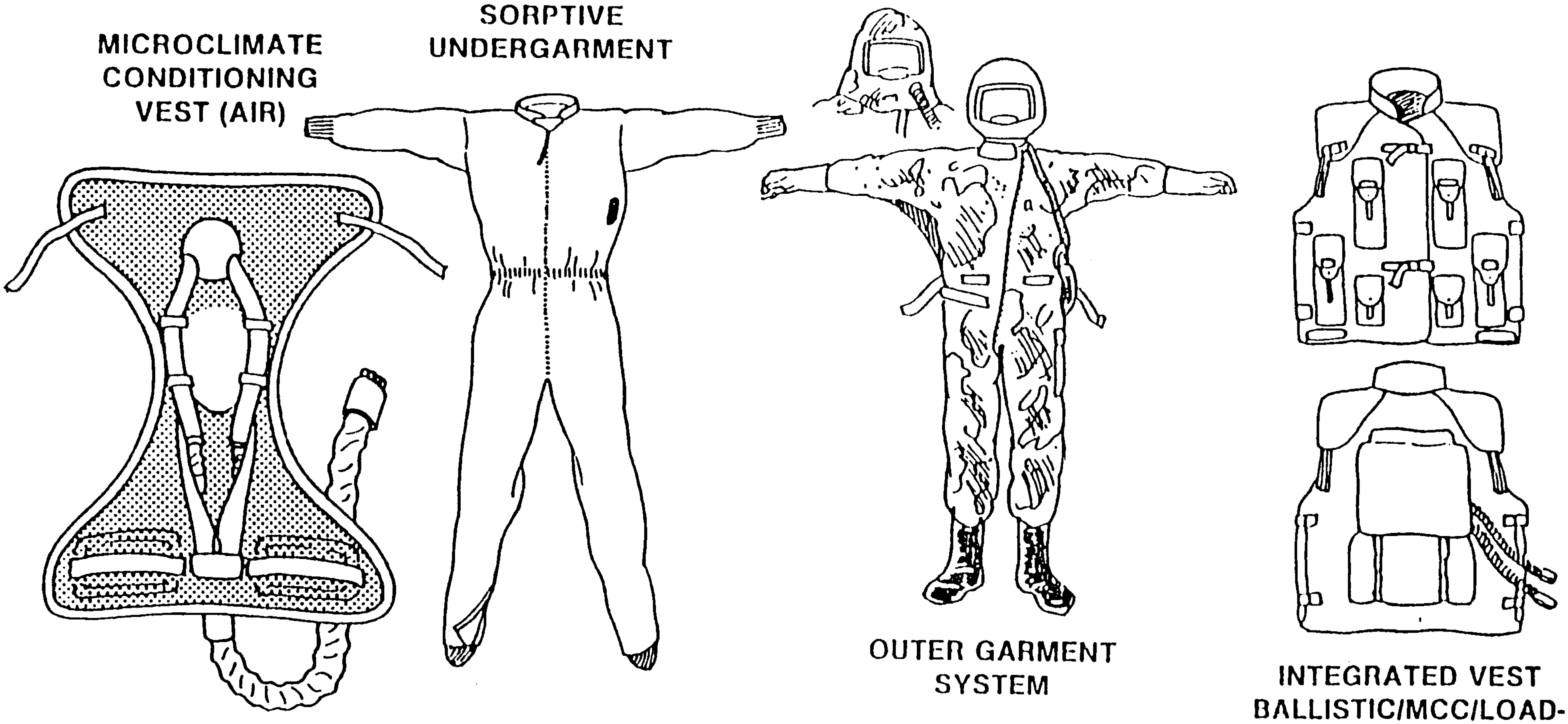
Shell Material	Protection Offered
• 4.5 OZ/SQ YD Woodland 79/20/1 Nomex/PBI/ Stainless Steel Laminated to a Semi-Permeable Membrane	• Flame/Thermal • Liquid/Aerosol • Visual/Infrared • Environmental • Permanent Anti-Stat • Microwave Attenuation

R&D on Integrated Protection

REDLEG High Technology Demonstration

- 72 hours in MOPP II
- 54 hours in MOPP IV
- Success due to integration of:
  - Microclimate conditioning
  - Thru-mask feeding
  - Thru-suit waste elimination
  - Entry/exit concepts

•ADVANCED INDIVIDUAL PROTECTIVE SYSTEM (AIPS) 6.3a TECH DEMO



User Requirements

- *Combat Vehicle Crewman's Protective Ensemble (CVCPE) Draft Operational & Organizational (O&O) Plan*
- *Maneuver Arms Tactical Protective System (MANTAPS) Draft O&O Plan*

SIPE 6.3A Tech Demo

User Input (US Army Infantry School)

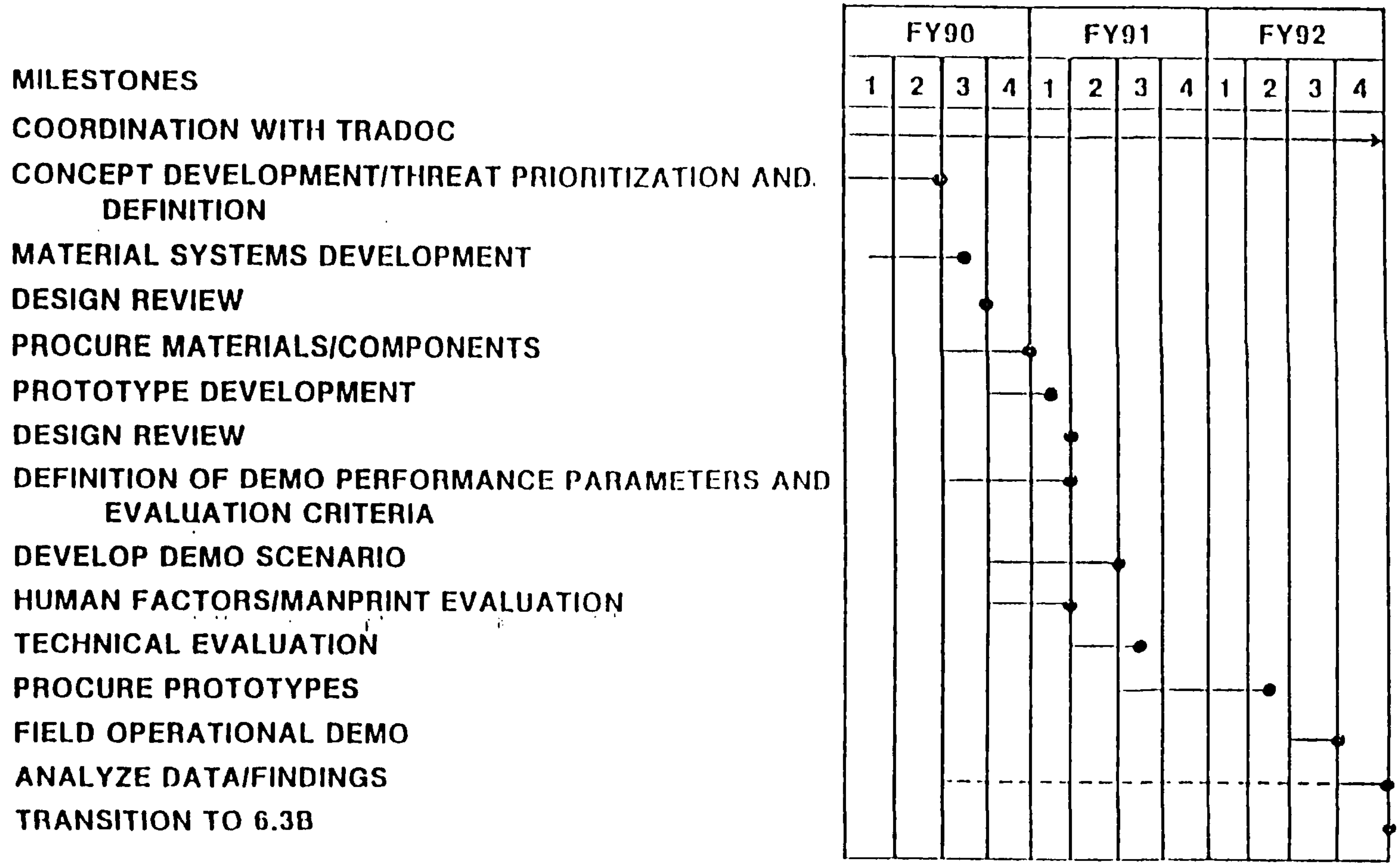
- Operational concept
- Performance/Protection requirements and priorities
- Definition of baseline system(s)
- Development of Demo scenario

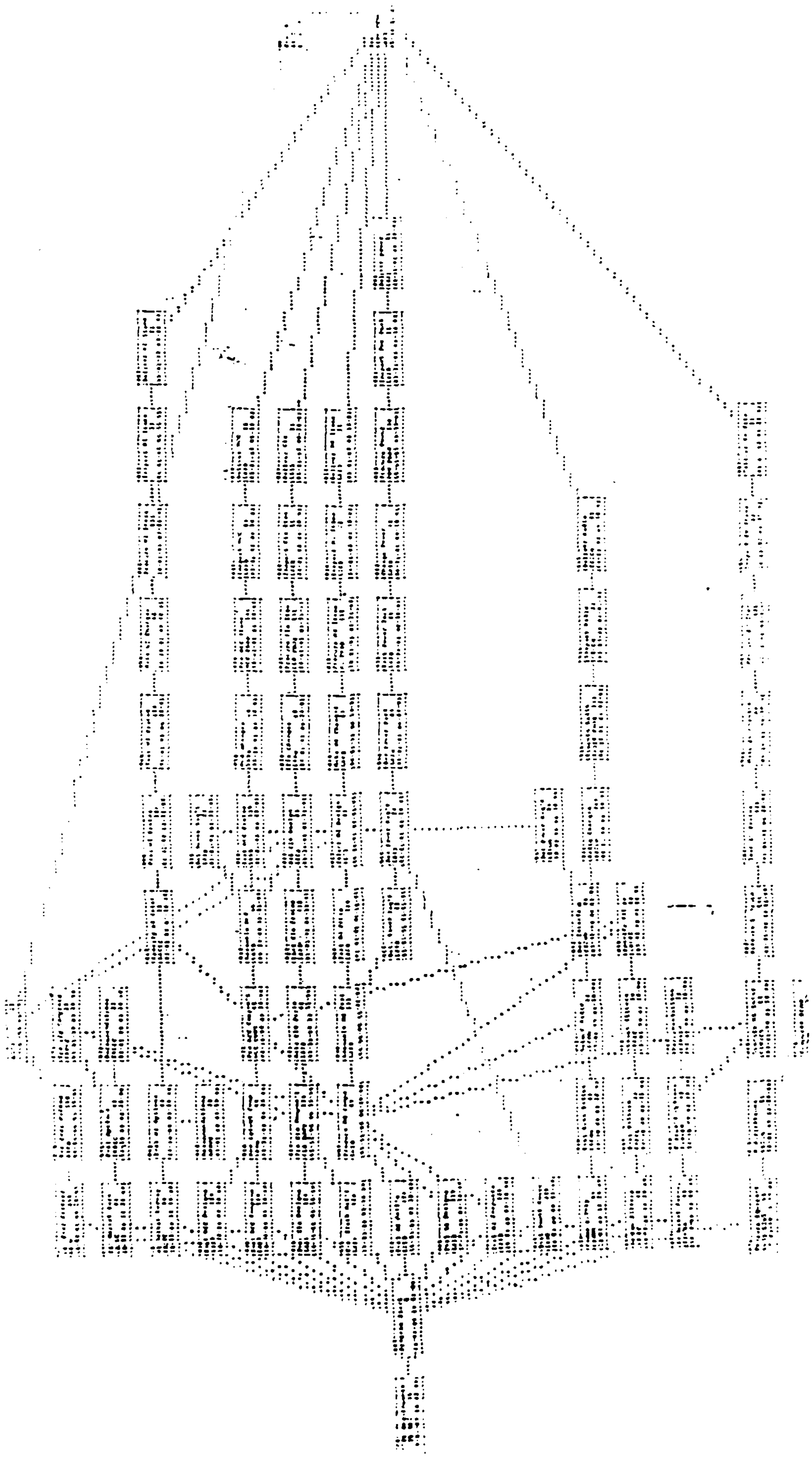
SIPE 6.3A Tech Demo

Funding Schedule

	FY90	FY91	FY92
MCC	640K	766	680
Clothing Systems	462	767	839
Integrated Headgear	495	671	722
Multi-Threat Armor	472	597	602
Handwear/Footwear	206	334	296
Test Support/Analysis	---	150	750
Total:	2275	3285	3889

MILESTONE SCHEDULE - 6.3A TECH DEMO





SIPE 6.3A Tech Demo

Field Demonstration

- Develop/Define measures of effectiveness
- Develop Demo scenario
- Conduct Demo
  - Fort Benning instrumented range and training areas
  - Human Engineering Laboratory obstacle course
- Analyze results

SIPE 6.3A Tech Demo

Expected Improvements

- Enhanced performance/survivability
- Improved communications
- Improved weapons interface
- Reduction in total weight/bulk - minimize functional redundancies within system

SIPE 6.3A Tech Demo

Enhanced Performance/Survivability

- Maintain Thermal Equilibrium
- Multi-Threat Protection
- Force Multiplication
- Mobility

CANE* Results	SIPE Pay-Off
- Radio transmissions 47% longer	- Individual soldier radio will allow encapsulated soldiers to communicate at least as effectively/efficiently as non-encapsulated soldiers.
- Radio transmissions increased more than 100% in number	
- Verbal face-to-face commo half as effective	- More effective use of weapon ranges due to more widely dispersed units
- More use of hand signals	

*Combined Arms in a Nuclear/Chemical Environment test program

SIPE 6.3A Tech Demo

Improved Weapons Interface

CANE* Results

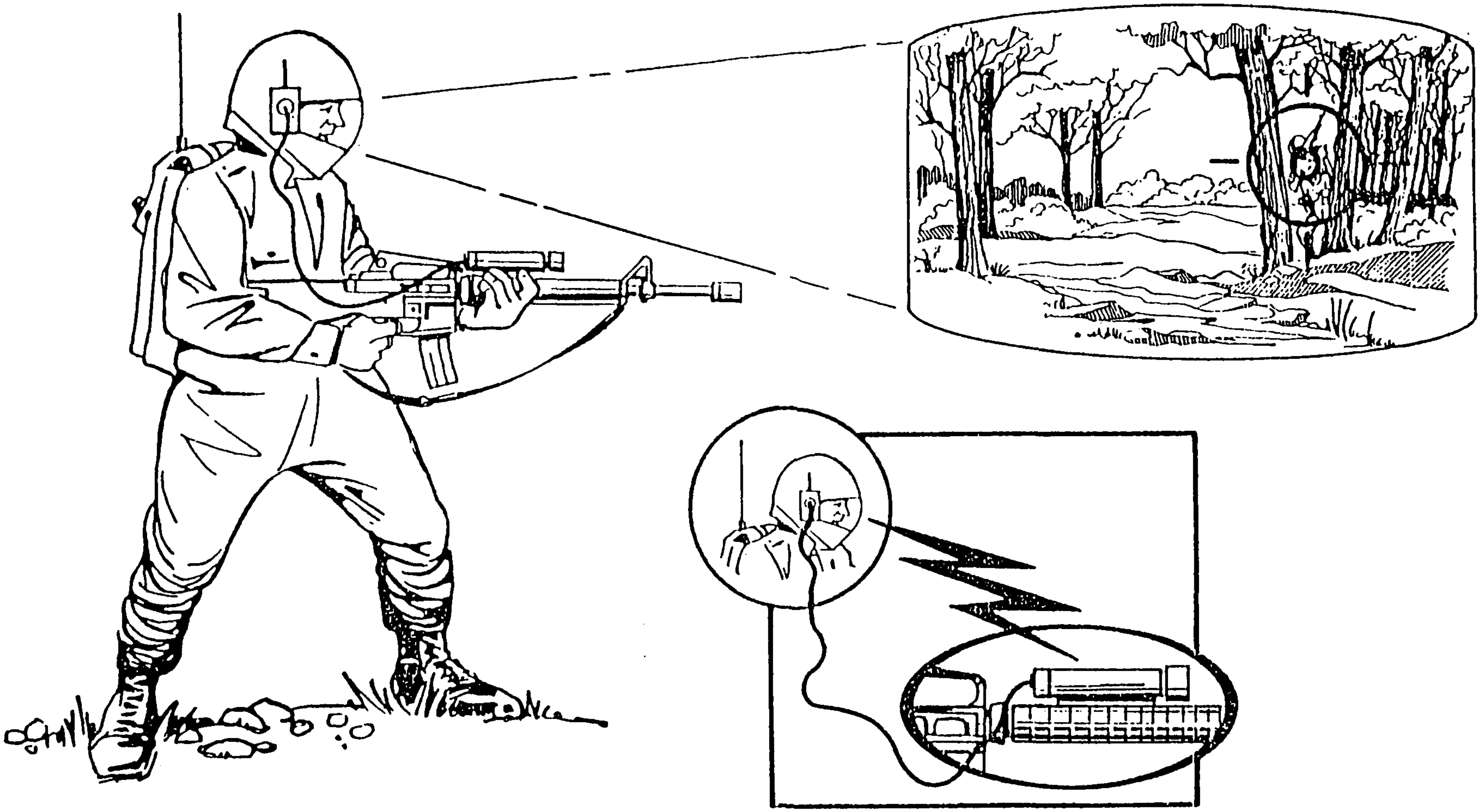
- Platoons took twice as long to complete an attack
- Firing rates declined 20% in the defense and 40% in the attack
- Difficulty locating and identifying targets
- Twice as many soldiers required for a successful attack

SIPE Pay-Off

- Integrated target acquisition/ fire control system will provide "shoot from the hip" capability, reduced acquisition/engagement time and greater probability of hit
- Increased lethality with lower volume fire
- Improved all-weather day/night capability over current systems

*Combined Arms in a Nuclear/Chemical Environment test program

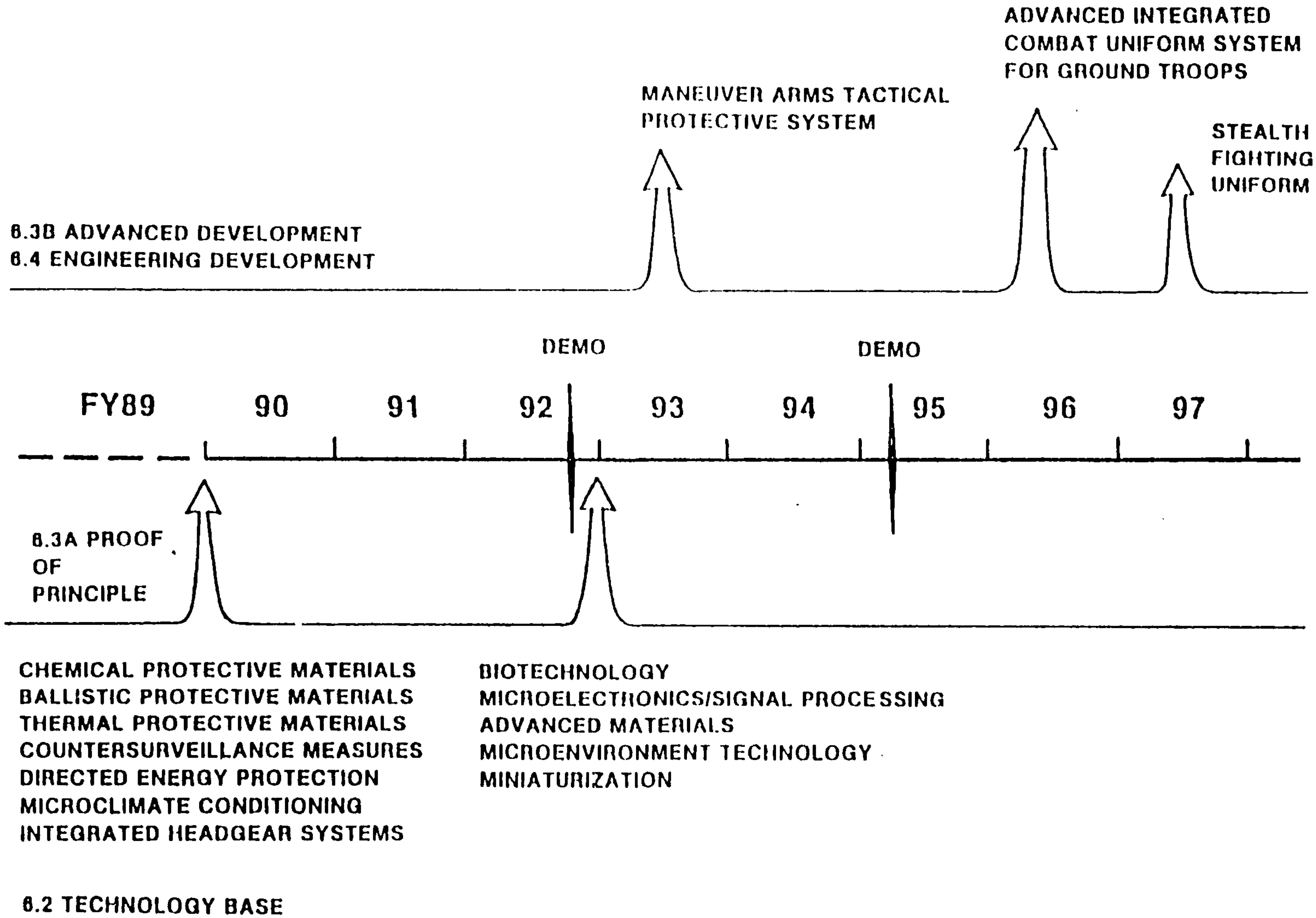
SIPE Weapon System Integration



Weight Reduction Goals

Current Gear (temperate)	35 lbs.
SIPE	25 lbs.*
	30% Reduction

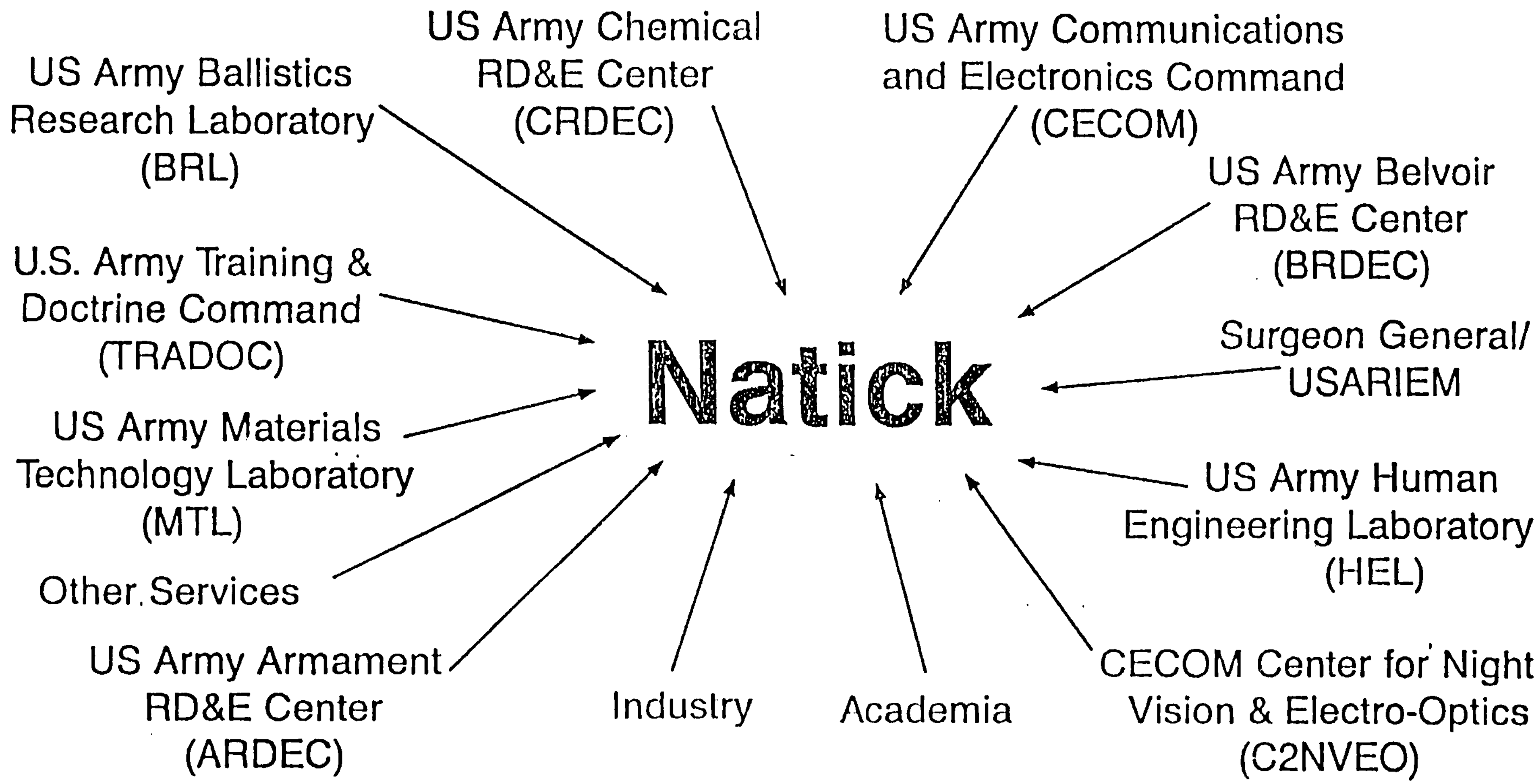
*Excluding Microclimate Conditioning Backpack



ADVANCED INTEGRATED COMBAT UNIFORM SYSTEM FOR GROUND TROOPS
MANEUVER ARMS TACTICAL PROTECTIVE SYSTEM
STEALTH FIGHTING UNIFORM
6.3B ADVANCED DEVELOPMENT
6.4 ENGINEERING DEVELOPMENT
DEMO
DEMO
FY89
90
91
92
93
94
95
96
97
6.3A PROOF OF PRINCIPLE
CHEMICAL PROTECTIVE MATERIALS
BALLISTIC PROTECTIVE MATERIALS
THERMAL PROTECTIVE MATERIALS
COUNTERSURVEILLANCE MEASURES
DIRECTED ENERGY PROTECTION
MICROCLIMATE CONDITIONING
INTEGRATED HEADGEAR SYSTEMS
BIOTECHNOLOGY
MICROELECTRONICS/SIGNAL PROCESSING
ADVANCED MATERIALS
MICROENVIRONMENT TECHNOLOGY
MINIATURIZATION
6.2 TECHNOLOGY BASE

SIPE 6.3A Tech Demo

Support From Outside Agencies



SIPE 6.3A Tech Demo

Support From Outside Agencies

- USA Chemical RD&E Center - Respiratory Protection, Testing
- USA Materials Technology Lab - Ballistics Materials Evaluation, Composites
- USA Ballistics Research Lab - Casualty Reduction Analysis, Materials Testing
- USA Belvoir RD&E Center - Lightweight Power Sources, MCC Support
- USA Communications and Electronics Command - Commo, Electronics
- USA Armament RD&E Center - Weapons Interface
- CECOM Center for Night & Electro-Optics - Night Vision, Weapons Sighting
- USA Human Engineering Lab - MANPRINT. Human Factors Support
- USA TRADOC - User Input, Test Support
- Surgeon General/USARIEM - Physiological Evaluations, Medical Support
- Other Services Industry, Academia


SIPE
SOLDIER INTEGRATED PROTECTIVE ENSEMBLE